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PROVISIONAL INTELLIGENCE REPORT

COMPUTATION OF INPUT REQUIREMENTS OF THE AIRCRAFT INDUSTRY OF THE USSR

CIA/RR PR-19

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Note

The data and conclusions contained in this report do not necessarily represent the final position of ORR and should be regarded as provisional only and subject to revision. Additional data or comments which may be available to the user are solicited.

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FOREWORD

This is the second of a series of provisional reports on the input requirements of the aircraft industry of the USSR.* It sets forth some tentative findings on input requirements -- in manpower, materials, and energy -- for the production of Soviet airframes and aircraft engines.

The purposes of this report are to provide a progess report, to identify significant inputs, to set forth some tentative findings, and to promote continuing discussions with those persons who may be of assistance in this study -- by calling attention to further avenues of investigation, by suggesting a sharpening of the methodologies employed, or by providing some of the additional tools and information required.

Since this is a provisional working paper, some substantive shortcomings and statistical inconsistencies may exist. In some cases, theoretical values and constants are subject to individual choice. In the final analysis the fact that time and manpower are limited suggests that these scant resources be applied to pushing on with the job at hand rather than to explaining why minor inconsistencies may exist.

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* Analysts are referred for background information to the first provisional report on the subject, CIA/RR PR-8, Input Requirements of the Aircraft Industry of the USSR, 20 Oct 1951. TOP SECRET.

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(Issued Separately)

NOTE ON CLASSIFICATION

The over-all classification of this report is SECRET. Some pages, however, are of lower classification and are so designated.

CIA/RR PR-19
(ORR Project 38-51)

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SECURITY INFORMATION

COMPUTATION OF INPUT REQUIREMENTS OF THE AIRCRAFT INDUSTRY OF THE USSR*

Summary

Manpower requirements for Soviet airframe and aircraft engine production have been computed in this report for several models which have received considerable study. The computations are based on an equation developed out of US and UK experience. Future work on manpower requirements should include study of other models; work on propellers, accessories, and spare parts; and research aimed at determination of concrete values for the variables used in computing manpower inputs.

The material requirements of the Soviet airframe and aircraft engine industries have been computed in this report for the same aircraft and aircraft engines considered in computing manpower requirements on the basis of inputs for US types comparable for this purpose, with allowance made for known and estimated differences in the Soviet types. Future work on material requirements should include study of additional types; verification of tentative weights; determination of input weights for propellers, tires, radios, and other equipment not included in the above tabulation; determination of the average proportion of rejects in Soviet plants; and investigation of the number of spare parts required by the Soviet Air Force per airplane and engine.

The energy requirements of the Soviet airframe and engine industries have been computed in this report for a given weight of product by analyzing the energy requirements of a hypothetical plant in each industry, assessing its requirements item by item and adding to obtain total requirements for each type of energy. These computations have been made on the basis of US data and roughly adjusted for the USSR with such meager data as are available. Future work on energy inputs should include more detailed research on each separate item of equipment and each process in the plant, study of propeller and accessory plants, and acquisition and use of additional over-all data for checking computed energy input requirements.

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* This report contains information available to CIA as of 15 May 1952.

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I. Computation of Manpower Input Requirements.

Manpower inputs for Soviet airframe and aircraft engine production have been computed on the basis of an equation developed by combining the work of 1/* and the work done during World War II by Dr. T.P. Wright, then of the US Aircraft Production Board. 2/

A. Requirements for Airframe Production.

1. The curve of man-hours per pound of aircraft versus percent of maximum output will vary in the same manner as the energy input curve. In the case of energy, there exists a minimum or "maintenance" energy input level, to which is added the incremental energy needed for production. Similarly, in the case of manpower, there is an almost constant "indirect" labor component, plus the incremental "direct" labor used in production. The ratio of direct to total labor may run from 40 to 60 percent in Soviet aircraft plants at peak production. 3/ These relations may be expressed by using the method developed by Dr. Wright 4/:

$$E = D + F + A \qquad (1)$$

where E = total workers

F = indirect factory workers (assumed to be 50 percent proportional to output and 50 percent independent of output)

D = direct factory workers (proportional to output)

A = office, administrative, and other overhead workers (assumed to be independent of output)

In terms of percent of maximum output, P,

$$E = (P/100)\,(D + F/2) + (A + F/2) \qquad (2)$$

If

$$D_{100} = WE_{100} \qquad (3)$$

(where W = ratio of direct to total workers at 100-percent production), then, substituting equation (3) in equation (1),

$$E_{100}\,(1-W) = F + A$$

$$A = E_{100}\,(1-W) - F \qquad (4)$$

Substituting equation (4) in equation (2),

$$E = (P/100)\,(D_{100} + F/2) + E_{100}\,(1-W) - F/2 \qquad (5)$$

* Footnotes in arabic numerals are to sources listed in Appendix M.

2. The number of direct workers will decrease with the cumulative number of aircraft produced, along an "80 percent curve" or similar function. The general form of this equation is

$$y = ax^n$$

in which, for a given model in a given plant,

y = direct man-hours required per pound of airframe number "x"
a = direct man-hours required per pound of airframe number one
x = cumulative airframe number
n = constant factor (representing slope of line)

From the above equation may be obtained the following equation for D = direct workers 5/:

$$D = \frac{NGax^n}{ce} \qquad (6)$$

where
N = airframes per month
G = airframe weight
c = monthly shift-hours worked
e = effective work factor

By substituting equation (6) in equation (5), the following equation may be obtained for total number of workers at the point when airframe number "x" of a given model is being produced in a given plant:

$$E = (P/100) \quad \frac{N_{100}Gax^n}{ce} + F/2 + E_{100}\,(1-W) - F2 \qquad (7)$$

3. Eleven terms are contained in equation (7):
E = total number of workers
P = percent of maximum output being produced
N = number of airframes being built per month
x = cumulative airframes of given model being produced in that plant
G = airframe weight (structural) built in plant
C = monthly shift-hours worked
e = effective work factor
a = direct man-hours per pound of first airframe produced
n = exponential factor
W = percent of direct to total workers
F = number of indirect factory workers

Of the above 11 terms, 4 are variable -- "E" (the solution) and "P," "N," and "x" (the prime variables) -- and the other 7 terms are constants. It is upon the accurate determination of the values of the constants that the validity of the solution depends.

4. Some work has been done on each of the constants listed, but the results leave much to be desired:

a. Airframe structural weights, "G": this factor is known for some Soviet aircraft, not for all. 6/ Unpublished ORR aircraft plant studies should be consulted for subcontracting as it affects the input requirements of specific Soviet airframe plants.

b. Direct man-hours per pound of airframe, "a": this factor has been estimated by 7/ and by the US Air Force, 8/ but not for Soviet aircraft. A method of determining analogies has not become evident.

c. Exponential factor, "n": this factor has been treated in many sources. 9/ Average values may be derived by airplane type, from past performance, but means to predict values for new types are not evident. The commonly used value for "n" is -1/3.

d. Monthly shift-hours, "c": this factor has been studied by the 10/ and by ORR. 11/ A considerable amount of basic data is to be found in unpublished ORR Soviet aircraft plant studies.

e. Effective work factor, "e": this factor has been studied by 2/ and is discussed briefly in the present report (see Appendix A). More work needs to be done on this subject.

f. Ratio of direct to total workers, "W", and number of indirect factory workers, "F": these factors have been discussed inconclusively by the 13/ and by ORR. 14/

5. Values have been computed by 15/ for direct man-hours per pound of the thousandth airframe of the types dealt with in the present report. To use these data, equation (7) may be altered by letting a' = computed direct man-hours for the thousandth airframe produced, so that, if $x = 1{,}000$, then, $a' = ax^n$

By the insertion of these values, equation (7) may be made to read

$$E = (P/100)\ \frac{N_{100}Ga'}{ce} + F/2 + E_{100}\ (1-W) - F/2 \qquad (8)$$

6. The other values chosen for the present report are as follows. Three are based on 16/:

$c = 182 \quad e = 0.70 \quad W = 0.50$

The fourth is assumed, based on Dr. Wright's calculations 17/:

$F = 3A$

If $W = 0.5$ and $F = 3A$, then from equation (4) it follows:

$0.5E_{100} = F + F/3$

$F = 0.375E_{100}$

By inserting these values in equation (7), an equation is obtained for output at 100 percent of capacity:

$$E_{100} = (1)\left(\frac{N_{100}Ga'}{(182)(0.7)} + \frac{0.375E_{100}}{2}\right) + 0.5E_{100} - \frac{0.375E_{100}}{2} \qquad (10)$$

$$0.5E_{100} = \frac{N_{100}Ga'}{127.4}$$

$$E_{100} = \frac{N_{100}Ga'}{63.7} = 0.0157\ Ga' \text{ per aircraft}$$

The equation for output at 20 percent of capacity is

$$E_{20} = (.2)\left(\frac{5N_{20}Ga'}{(182)(.7)} + \frac{0.375}{2}\,\frac{5N_{20}Ga'}{63.7}\right) + \frac{(0.312)(5)N_{20}Ga'}{63.7} \qquad (11)$$

$$= \frac{Ga'}{127.4} + \frac{Ga'}{339.7} + \frac{Ga'}{40.8} = 0.03528\ Ga' \text{ per aircraft}$$

7. By substituting in equations (10) and (11) concrete values for airframe structural weight "G" and direct man-hours per pound of thousandth airframe "a'", manpower inputs may be computed for the production of airframes. These are given in Table 1.

Table 1

Manpower Requirements for Soviet Airframe Production a/

Aircraft	G (Airframe Structural Weight, Lbs)	a' (Direct Man-Hours per Lb)	Number of Workers Required to Produce 1 Airframe in 1 Month	
			E_{100} (at 100 Percent of Capacity)	E_{20} (at 20 Percent of Capacity)
MIG-15	4,000 b/	1.66	104	234
Il-12	13,300 c/	1.56	326	732
Tu-4	35,100 c/	1.39	766	1,721
Li-2	9,100 c/	3.03	433	973
Il-18	19,500 c/	1.73	530	1,190
Type 31	49,000 d/	1.00	769	1,729

a. For the thousandth airframe of a given model produced in a given plant.
b. Based on analysis by US contractor. 18/
c. Based on USAF analysis. 19/
d. From earlier CIA/RR report. 20/

B. Requirements for Aircraft Engine Production.

1. For engines, curves of data such as that used above do not exist. A makeshift set of curves, based on incomplete data, has been prepared. The data are given in Tables 2 and 3.

Table 2

Data for Computing Manpower Requirements for Piston Engine Production

Engine	Direct Labor Requirements a/ (Man-Hours)	Displacement b/ (Cu In)	Take-Off Power b/ (Brake Hp)	Type b/
VK-107	2,500	2,135	1,630	VEE-12
AM-42 and 45	3,000	2,850	1,975	VEE-12
Ash-21	1,100	1,410	690	Radial- 7
Ash-82	3,300	2,495	1,825	Radial-14
Ash-90	3,900	3,350	2,200	Radial-18
M-11	800	526	158	Radial- 5
R-3350-26W	2,000	3,350	2,200	Radial-18

a. figures, 21/ except for the figure for the R-3350-26W, which is taken from a CIA/RR report. 22/
b. Air Intelligence Center (ATIC) figures. 23/

Table 3

Data for Computing Manpower Requirements for Jet Engine Production

Engine	Direct Labor Requirements a/ (Man-Hours)	Dry Weight b/ (Lbs)	Take-Off Thrust b/ (Dry Weight, Lbs)	Type b/
Russian Nene (RD-45)	5,000	1,850-1,900	4,900-5,100	Centrifugal-1-
German 003	1,500-2,000	1,375	2,250	Axial flow-7-1
Russian 004	2,500	1,650	2,200	Axial flow-8-1
German 004 (1st)	3,200	1,650	2,200	Axial flow-8-1
German 004 (20,000th)	850	1,650	2,200	Axial flow-8-1
J-48	1,950	2,700	6,250	Centrifugal-1-

a. figures, 24/ except for the figure on the J-48, which is taken from a report of a US aircraft company. 25/
b. ATIC figures. 26/

One US authority 27/ cites displacement as a superior index to power for production when estimating from floor space. Curves plotted from the above data tend to contradict this thesis for man-hours. For jet engines, dry weight appears (on slim evidence) to be the index, as indicated in Figure 1.*

2. On the basis of these curves, it is possible to arrive at an equation for total man-hours on the assumption that equation (2) is valid for engine plants and that the thousandth engine is being built except in the case of the Ju-224. Man-hours for the Ju-224 have been computed for the hundredth engine.

For production at 100 percent of capacity, using equation (5), we can obtain Ga' = D' directly from Figure 1:

$$E_{100} = (1)\ (D_{100} + F/2)\ E_{100}\ (1-0.5) - F/2$$

$$E_{100} = 2D_{100} = \frac{2\ (\text{direct man-hours per engine})}{(182)\ (0.7)} = 0.0157D'$$

For production at 20 percent of capacity

$$E_{20} = (0.2)\left(\frac{5N_{20}D'}{(182)\ (0.7)} + \frac{0.375}{2}\ \frac{(5N_{20}D')}{63.7}\right) + \frac{(0.312)\ (5)\ N_{20}D'}{63.7}$$
$$= 0.03528D'$$

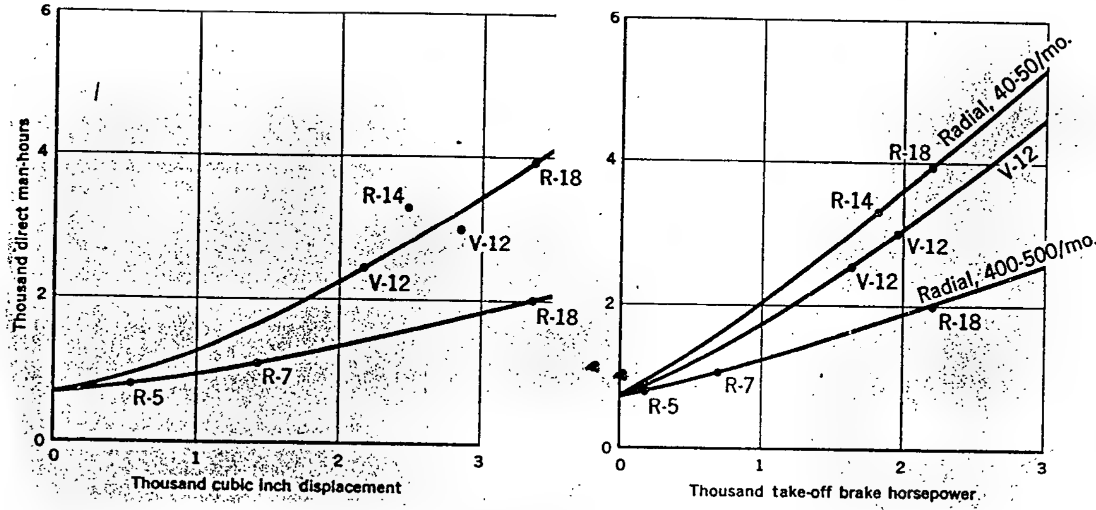
3. By substituting in the above equations concrete values for "D'" (direct man-hours per engine) taken from the curves plotted in Figure 1, manpower inputs may be computed for the aircraft engines under study in this report. These are given in Table 4.**

II. Computation of Material Input Requirements.

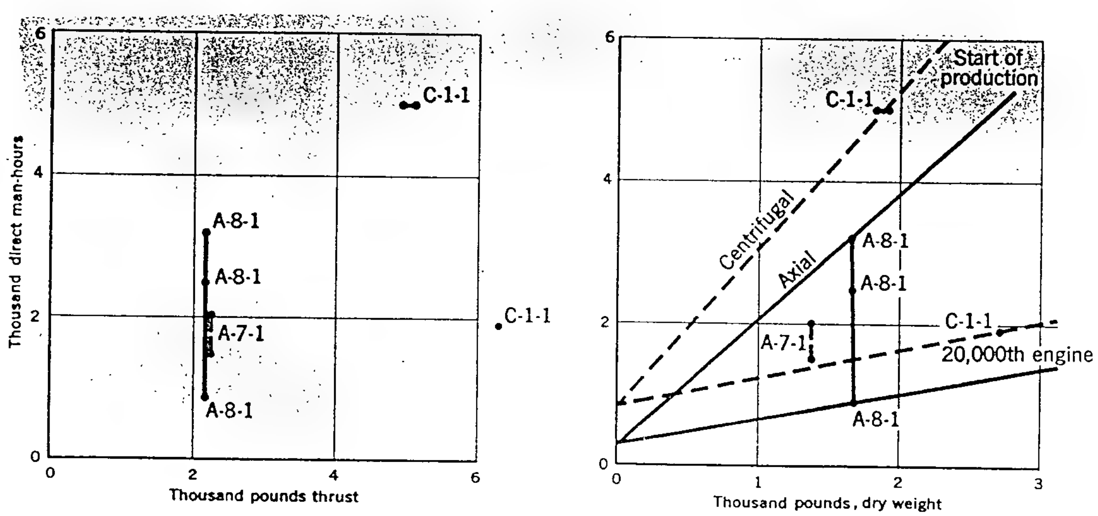
Material inputs have been computed tentatively for the Soviet airframe and engine industries, in part by analogy with comparable US types and in part from the analyses that have been made of captured Soviet equipment. Weights given are mostly AMPR*** (Aeronautical Manufacturers Planning Reports)

* Figure 1 follows p. 7.
** Table 4 follows on p. 8.
*** AMPR airframe weight is weight empty, less the following: engine, turbosuperchargers, starter, accessories, propeller (hubs, blades, control, governor), wheels (tires, tubes, brakes), auxiliary power plant, radio and radar units (not installation parts and wiring), battery, generator, storage items (first-aid kits, removable fire extinguishers, flight manuals, etc.).

MANPOWER REQUIREMENTS FOR AIRCRAFT ENGINE PRODUCTION



Piston Engines



Jet Engines

Table 4

Manpower Requirements for Soviet Aircraft Engine Production a/

Engine	D' (Man-Hours per Engine)	Number of Workers Required to Produce 1 Engine in 1 Month: E_{100} (at 100 Percent of Capacity)	E_{20} (at 20 Percent of Capacity)
Vk-1	3,750	58.9	132.3
Ash-82	2,900	45.5	102.3
Ash-90	3,400	53.4	120.0
M-62	2,400	37.7	84.7
Ju-224 a/	4,800	75.4	169.3

a. For the thousandth aircraft engine of a given model produced in a given plant, except for the Ju-224. Requirements for the Ju-224 are for the hundredth engine produced in a given plant.

airframe weights. To obtain total inputs, it will be necessary to add the nonairframe items such as engines, tires, propellers, and radio. The weights are tentative because they have not been examined in sufficient detail to determine their completeness.

Future work on material inputs will include: (1) verification of tentative weights; (2) determination of input weights for additional aircraft and aircraft engines; (3) determination of input weights for propellers, tires, radio, etc.; (4) determination of average amount of rejects in Soviet plants; and (5) determination of amount of spares required by the Soviet Air Force, per unit aircraft and engine.

A. Requirements for Airframe Production.

1. The finished weight has been estimated and the bill of materials has been compiled in detail by ORR for the structure of a captured MIG-15 (see the Annex).* As a check on detail weights, the ORR calculated weights have been compared with an actual weight statement for the captured MIG, and adjustments have been made to compensate for parts missed in the calculations. Tentative totals for each material input have been checked and in certain cases revised in the light of a preliminary material breakdown on the MIG-15 by the Air Technical Intelligence Center (ATIC).

* The bill of materials for the MIG-15 drop tank has also been prepared from a description of a recovered tank, with allowance for scrap. The calculated weight checks with the actual weight. Appendix B contains these data.

A summary of the data is presented in Table 5.* The data shown approximate AMPR airframe weight plus landing gear, with allowance for scrap, but should be checked in more detail for compliance with AMPR definition. Work is in progress on this subject.

2. Input data for the other Soviet aircraft dealt with in this report -- Il-12, Tu-4, Li-2, Il-18, and Type 31 -- have been compiled from information furnished for US aircraft. (Some of the basic data, partly taken from an earlier report 29/, are presented in Appendixes C, D, and E.) Bill-of-materials data for the B-29 (and therefore for the Tu-4 and Type 31) appear to be incomplete, despite claims to the contrary by USAF procurement personnel. The first four listed are directly comparable to specific US types. Data for the fifth -- the Type 31 -- have been computed from the Soviet Tu-4. The points of comparison are shown in Table 6.** On the basis of the comparisons shown in Table 6, material requirements have been tentatively compiled for the Soviet aircraft listed. These requirements are given in Table 7.***

B. Requirements for Aircraft Engine Production.

1. Input data for four of the Soviet aircraft engines dealt with in this report -- the VK-1, the Ash-90, the Ash-82, and the M-62 -- have been compiled from information furnished for comparable US types. (Some of the basic data, partly taken from an earlier report, 30/ are presented in Appendixes E and F.) By analogy with these data, input data have also been estimated for the Ju-224, which has no close US analogy. The tentative results obtained are presented in Table 8**** and Table 9.*****

2. The Ju-224 is the equivalent of four "Vee" engines without cylinder heads. It should therefore approach the ratios of the R-1820 and the R-2600, with a decrease in aluminum to allow for absence of cylinder heads. This would be at least partially compensated by the excess number of crankcases. In the absence of more detailed breakdown (which should be undertaken in the future), an average of R-1820 and R-2600 ratios was used. The weights shown above for the Ju-224 have been computed from these averages and the base of a reported weight of 2,500 kilograms (about 5,500 pounds) for the Ju-224. (See Tables 8 and 9.)

* Table 5 follows on p. 10.
** Table 6 follows on p. 12.
*** Table 7 follows on p. 14.
**** Table 8 follows on p. 15.
***** Table 9 follows on p. 15.

Table 5

Summary of Data for Estimating Material Requirements
for the MIG-15 Airframe a/* and Landing Gear

Pounds

	ORR Estimates												Cornell Laboratory Measurements b/
	Aluminum and Alloys		Steel (including Stainless Steel) c/		Magnesium and Alloys		Rubber		Glass and Plastics		Totals d/		
	Input Weights	Finished Weights	Input Weights	Finished Weights	Input Weights	Finished Weights	Input Weights	Finished Weights	Input Weights	Finished Weights	Input Weights	Finished Weights	Total Finished Weights
Wing Group	979	772	1,183	546							2,162	1,318	1,400
Tail Group	228	166	887	270	1	1					1,116	437	413
Body Group	1,094	952	428	415					44	44	1,566	1,411	1,470
Main Landing Gear			510	137	103	20	56	56			669	213	524
Nose Landing Gear			335	88	56	10	28	28			419	126	150
Fuel Tanks	35	29					85	85			120	114	115
CIA/RR Estimated Totals d/	2,336	1,919	2,343	1,456	160	31	169	169	44	44	6,052	3,619	4,072

* Footnotes to Table 5 follow on p. 11.

Table 5

Summary of Data for Estimating Material Requirements
for the MiG-15 Airframe a/ and Landing Gear
(Continued)

Pounds

	ORR Estimates											
	Aluminum and Alloys		Steel (including Stainless Steel) c/		Magnesium and Alloys		Rubber		Glass and Plastics		Totals d/	
	Input Weights	Finished Weights	Input Weights	Finished Weights	Input Weights	Finished Weights	Input Weights	Finished Weights	Input Weights	Finished Weights	Input Weights	Finished Weights
ATIC preliminary breakdown e/		3,250		1,620		140		200		210		5,420
Revised totals	3,970 f/	3,250 f/	3,340 g/	1,460 g/	160 h/	30 h/	260 i/	200 i/	270 j/	210 j/	8,000	5,150

a. Approximately ... airframe.
b. Cornell Laboratory figures 23/ also include the following finished-weight data (in pounds):

Engine	1,850	Engine Starters	35	Fuel System	235
Engine Accessories	160	Lube System	25	Piping, etc.	120
Engine Controls	15			Fixed Equipment	1,030

c. Stainless steel is included in the body group, as follows: input weight, 52 pounds; finished weight, 39 pounds. These figures are included in the totals.
d. These totals differ slightly from those given in the Annex to this report because the component figures have been rounded to the nearest unit.
e. Unpublished figures obtained directly from ATIC.
f. It is assumed that the ATIC figure of 3,250 pounds for finished weight of aluminum is correct. To obtain a corresponding bill-of-materials figure, the ratio of the ORR estimate for finished to bill-of-materials weight (about 1.22) has been used. If 615 pounds of extrusions were omitted from the ORR estimates, the ratio would be 1.33.
g. ORR figure.
h. ORR figures; it is believed that wheel brake weight has been erroneously included in the ATIC preliminary breakdown for finished wheel weight.
i. ATIC preliminary breakdown for finished rubber weight is used because it contains some hose items not in the ORR estimate. Bill-of-materials weight is derived therefrom.
j. ATIC preliminary breakdown is used for glass and plastics finished weight. Bill-of-materials weight is derived therefrom.

Table 6

Comparative Statistics on Soviet and US Aircraft

Weights in Pounds

Model		Known Finished Weights				Weight Ratios			Estimated Finished Weight		Bill-of-Materials Weight	
Soviet	US	Structure a/*	Airframe b/	Empty c/	Maximum Take-Off d/	Airframe Structure	Empty Structure	Empty Airframe	Structure	Airframe	Known	Estimate
	T-29A		13,600	23,800	39,600			1.5	13,300		27,260	
Il-12		13,300			38,000					18,600		27,260
Tu-4	B-29	35,100	48,000	71,500	140,000	1.4	2.0	1.5			47,225 f/	
Li-2	C-47, R4D, DC-3	9,100	12,500	17,000	29,000	1.4	1.9	1.4			15,000	
	C-54, R5D, DC-4	19,500	28,000	38,000	82,500	1.4	1.9	1.4			39,992	
	R6D, DC-6B	25,900	37,000	55,000	112,000	1.4	2.1	1.5			70,069	
Il-18			28,000		87,000					19,500		40,000

* Footnotes to Table 6 follow on p. 13.

Table 6

Comparative Statistics on Soviet and US Aircraft
(Continued)

Weights in Pounds

Model		Known Finished Weights				Weight Ratios			Estimated Finished Weight		Bill-of-Materials Weight	
Soviet	US	Structure a/	Airframe b/	Empty c/	Maximum Take-Off d/	Airframe Structure	Empty Structure	Empty Airframe	Structure	Airframe	Known	Estimate
Type 31 e/				97,700 (1.37)	225,000 (1.61)				49,000 (1.40)	65,000 (1.35)		67,510 e/ (1.43)

a. Figures from Air Technical Intelligence Center (ATIC) and Navy Bureau of Aeronautics (BuAer).
b. Figures from Civil Aeronautical Administration (CAA), ATIC, and BuAer.
c. Figures from US Air Force (USAF) and BuAer.
d. Figures from USAF, ATIC, and BuAer.
e. Figures in parentheses underneath finished weights for the Type 31 are ratios with parallel figure for the Tu-4. From an average of these ratios is derived the ratio 1.43 for bill-of-materials weights, and from this ratio is computed the bill-of-materials figure (67,510 pounds) for the Type 31.

Table 7

Material Requirements for Soviet Airframe Production

Item	Aluminum and Alloys	Steel and Iron	Stainless Steel	Magnesium and Alloys	Rubber	Glass and Plastics	Copper and Alloys
							Pounds
Il-12	19,700	1,570	1,670	760	185	2,560	1,135
Tu-4	34,000	7,950	20	280	3,375	330	1,270
Li-2	11,600	2,040	730	65	132	40	481
Il-18	31,000	4,300	2,110	910	143	41	773
Type 31 a/	48,600	11,370	30	400	4,820	470	1,820

a. Type 31 figures are computed from Tu-4 figures at the ratio 1.43. See above, Table 6, footnote e.

Table 3

Material Requirements for Soviet Aircraft Engines

Pounds

Soviet Engine	Comparable US Type	Aluminum and Alloys	Steel	Magnesium and Alloys	Rubber	Copper and Alloys	Total Weight of Inputs	Total Finished Weight (Dry)
VK-1 a/	J-48P-5	1,128	5,111 b/	653	-	8	6,900	2,725
ASh-82 c/	R-2600	1,375	6,200	32	10	214	7,657	1,980
ASh-90 c/	R-3350	2,760	7,000	620	7	300	10,689	2,670
M-62 c/	R-1820	1,110	3,724	0	10	35	4,882	1,200
Ju-224 d/	-	4,400	17,150	165	55	385	22,155	5,500

a. Taken directly from J-48P-5 figures given in Appendix F.
b. Includes 742 pounds of stainless steel.
c. Computed from dry weights and bill-of-materials ratios for US aircraft engines given in Table 9, below.
d. Averaged from bill-of-materials ratios given for R-1820 and R-2600 engines in Table 9, below, applied to dry weight figure of 2,500 kilograms given by AIC for the Ju-224.

Table 9

Ratios for Computing Material Requirements for Soviet Aircraft Engines

Percent of Dry Weight

	Aluminum and Alloys	Steel	Magnesium and Alloys	Rubber	Copper
R-2600	69	313	3	1	11
R-3350	103	262	23	003	11
R-1820	92	311	0	1	3
(Ju-224) a/	(80)	(312)	(3)	(1)	(7)

a. Average of ratios for the R-1820 and the R-2600. See explanation in text, p. 9, above.

III. Computation of Energy Input Requirements.*

A. Requirements for Airframe Production.

1. To estimate the probable energy requirements for Soviet airframe production, a hypothetical plant has been constructed for the US and a Soviet counterpart has been constructed alongside it. The hypothetical plants, US and Soviet, based on a handy 1 million square feet of floor area, are assumed to turn out 700,000 pounds of airframe per month, at peak capacity, using three shifts. 31/ From US data, detailed computations have been made of the energy inputs required in the hypothetical US plant, and Soviet requirements have been estimated therefrom (See Appendix G). (In other words, over-all efficiencies are assumed to be the same.) A summary of these requirements is given in Table 10.

Table 10

Monthly Energy Requirements
for Hypothetical US and Soviet Airframe Plants
(Estimated Monthly Capacity of 700,000 Pounds of Product)

Million Btu

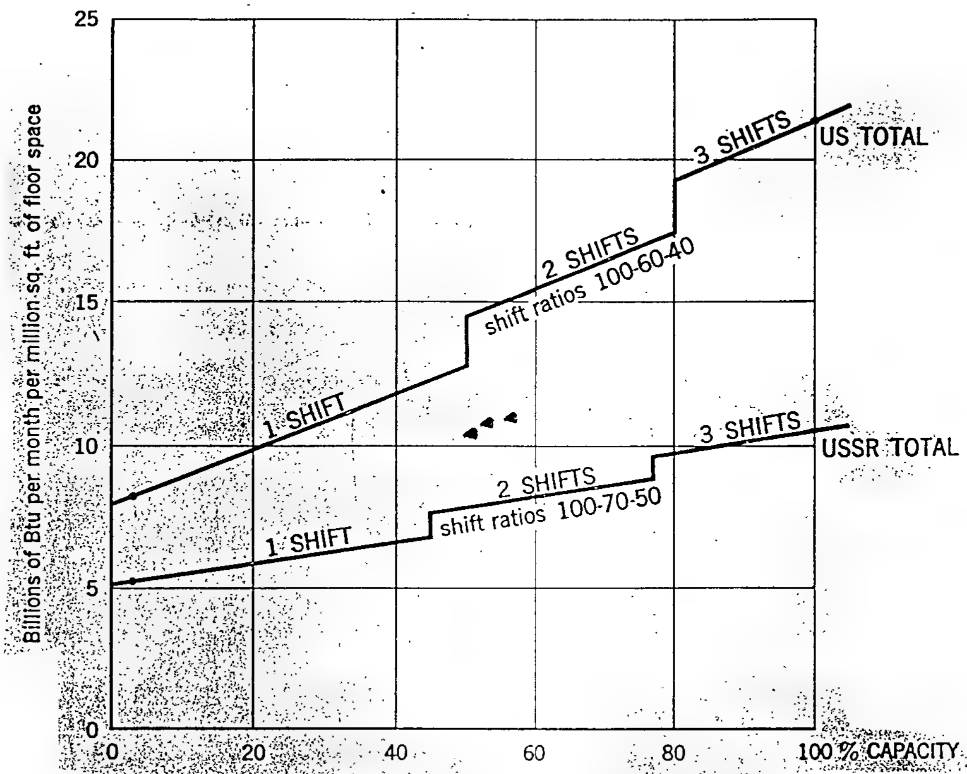
	At 100 Percent of Capacity		At 20 Percent of Capacity	At 3 Percent of Capacity	
	US	Soviet	Soviet	US	Soviet
Light	1,770	990	330	600.0	330.0
Comfort Heat	10,700	6,350	4,760	7,500.0	4,760.0
Electrochemical	752	102	20	22.5	3.1
Process Heat	181	181	36	5.4	5.4
Power	5,500	1,460	292	15.9	40.8
Miscellaneous	743	307	102	22.3	18.2
Run-Up	2,000	1,000	200	60.0	30.0
Total	21,646	10,390	5,740	8,226.1	5,187.5

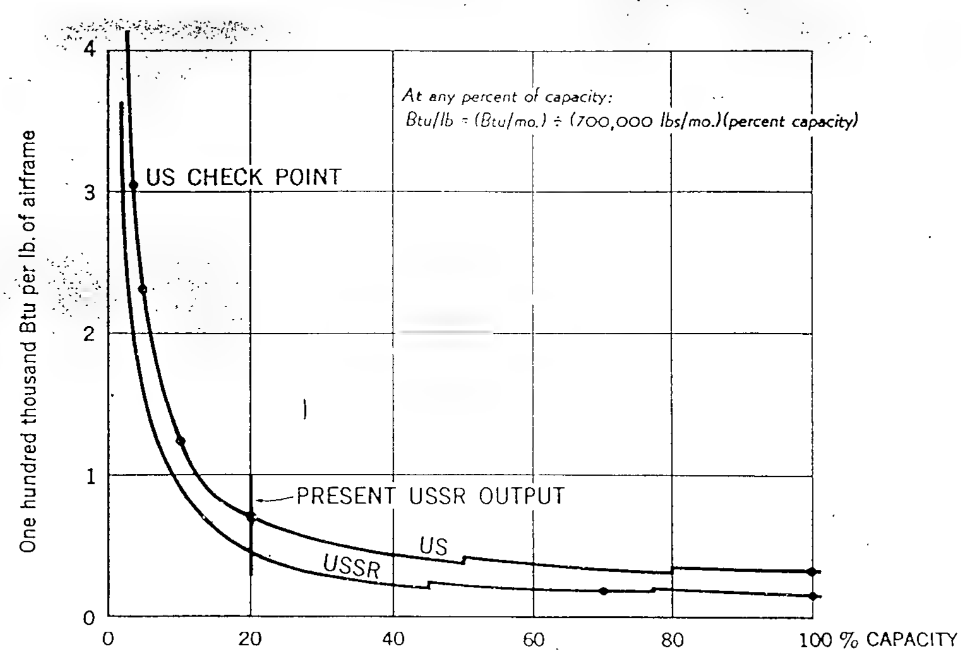
The data given in Table 10 have been plotted, and from them a pair of generalized curves of Btu per pound of airframe versus percent of production capacity has been calculated and plotted (in Figure 2).**

* It should be noted that energy is presented in terms of British thermal units (Btu) rather than in units of coal, oil, gas, or electricity. The reason for this is the partial interchangeability of energy sources, including manpower (as indicated in Appendix H).

** Figure 2 follows p. 16

ENERGY REQUIREMENTS FOR AIRFRAME PRODUCTION IN THE US AND THE USSR





2. There is one possible check on these data. In a previously published CIA/RR study a value of 302,000 Btu per pound of airframe was derived for the US industry in 1947. 32/ Peak US production was about 9,000 aircraft per month in 1944, with about 10,000 pounds average airframe weight. 33/ If this rate -- 1,080 million pounds of airframe per year -- is accepted as the US maximum rate, then in 1947, when US production was at the rate of 3,888,000 pounds of airframe per year, the US was operating at 3.6 percent capacity. This percentage, when plotted on Figure 2, falls (mirabile dictu) right on the calculated line. In view of the fact, however, that much of the floor space available to the US industry at peak war condition had been retired by 1947, it may be more reasonable to base the 1947 operating level on the amount of floor space actually available in 1947. To obtain this figure would require a considerable amount of research and may be considered to be a project for the future.

3. It cannot be assumed that distribution patterns of energy sources for the airframe industries of the US and the USSR coincide. In order to determine the actual energy sources, a survey was made of ORR Soviet aircraft plant studies completed to February 1952 (see Appendix I). This field should be resurveyed when the ORR plant and plant-complex studies have been carried to completion. On the basis of fragmentary evidence, the estimated monthly energy input requirements presented in Table 10 have been broken down by source of energy. The results are presented in Table 11.*

4. The data presented in Table 11 have been converted from Btu into the appropriate physical unit for each form of energy, and monthly energy input requirements have been computed in these terms per 100,000 pounds of airframe produced. These results are presented in Table 11a.**

B. Requirements for Aircraft Engine Production.

1. To estimate the probable energy requirements for Soviet aircraft engine production, the same method has been used as in estimating the probable energy requirements of the airframe industry -- a hypothetical plant has been constructed for the US, and a Soviet counterpart has been constructed alongside it. The US plant has been checked against the same US data used for the airframe industry. 34/ In order to permit the convenient use of certain data developed in estimating energy requirements for airframe production, the floor area of the hypothetical aircraft engine plants has been set at the same figure as that used for the hypothetical airframe plants -- 1 million square feet.

2. The basic model for the hypothetical US aircraft engine plant is an installation with a floor area of 4,727,000 square feet. Working

* Table 11 follows on p. 18.
** Table 11a follows on p. 19.

Table 11

Breakdown by Sources of Monthly Energy Requirements
of Hypothetical Soviet Airframe Plant
(Estimated Monthly Capacity of 700,000 Pounds of Product)

Million Btu

	Percentage by Source				At 100 Percent of Capacity						At 20 Percent of Capacity				
	Oil	Gas	Coal	Electricity	Oil	Gas	Coal	Electricity	Total	Reduction Factor	Oil	Gas	Coal	Electricity	Total
Light				100	0	0	0	990	990	1/3	0	0	0	330	330
Comfort Heat	5	11	84		318	698	5,334	0	6,350	3/4	238	524	3,998	0	4,760
Electrochemical				100	0	0	0	102	102	1/5	0	0	0	20	20
Process Heat	14	43	29	14	25	78	53	25	181	1/5	5	16	10	5	36
Power				100	0	0	0	1,460	1,460	1/5	0	0	0	292	292
Miscellaneous	50			50	153	0	0	153	307	1/3	51	0	0	51	102
Run-Up	100				1,000	0	0	0	1,000	1/5	200	0	0	0	200
Total					1,496	776	5,387	2,730	10,389		494	540	4,008	698	5,740
Correction for Plant Generation of Electric Power a/					109	0	574	-683			28	0	147	-175	
Corrected Total					1,605	776	5,961	2,047	10,389		522	540	4,155	523	5,740

a. The distribution of electric power by sources is estimated as follows: 75 percent is estimated to originate with the electric power grid, and 25 percent to originate in plant generators, of which coal is used to generate an estimated 21 percent and oil to generate an estimated 4 percent. See Appendix X.

Table 11a

Breakdown by Sources of Monthly Energy Requirements
of Hypothetical Soviet Airframe Plant
(Estimated Monthly Capacity of 700,000 Pounds of Product)

	At 100 Percent of Capacity					At 20 Percent of Capacity				
		Gas					Gas			
Monthly Requirements	Oil	Natural	Artificial	Coal	Electrical Power	Oil	Natural	Artificial	Coal	Electrical Power
Total in Million Btu	1,605	776		5,961	2,047	522	540		4,155	523
	Bbls	Thousand Cu Ft		Short Tons	Thousand Kwh	Bbls	Thousand Cu Ft		Short Tons	Thousand Kwh
Total in Physical Units a/	306 b/	697 c/	157 c/	229 d/	600 e/	98 b/	485 c/	110 c/	160 d/	153 e/
Requirements in Physical Units per 100,000 Pounds of Airframe	44	100	22.5	33	86	70	347	79	114	109

a. For the factor used for conversion from Btu into physical units, see a previously published CIA/RR report. 35/
b. 125,000 Btu per gal, 42 gals per barrel.
c. Based on use ratio of natural gas to artificial gas of 4.43; 1,000 Btu per cu ft for natural gas and 500 Btu per cu ft for artificial gas.
d. 13,000 Btu per lb; 2,000 lbs per ton.
e. 3,412 Btu per kwh.

at 100-percent capacity, this installation produces 1,000 J-48 engines (plus 20 percent of spare parts) per month. 36/ On this basis, the monthly capacity of the hypothetical plant of 1 million square feet (including capacity used to produce spare parts) may be computed at the equivalent of about 250 J-48 engines. The finished weight of the J-48 engine is 2,725 pounds. Expressed in terms of weight, then, the production of the hypothetical US aircraft engine plant, at 100 percent of capacity, may be given as roughly 675,000 pounds a month. Finished weight is apparently the best single common measure of energy input requirements for jet and piston engines (the equivalence of jet and piston power is subject to debate).

3. From data for the actual US plant used as a model, together with analogous data for airframe production, have been computed the energy requirements of the hypothetical US aircraft engine plant, from which the requirements of the hypothetical Soviet plant have been estimated (see Appendix J). A summary of these requirements is given in Table 12.

Table 12

Monthly Energy Requirements
for Hypothetical US and Soviet Aircraft Engine Plants
(Estimated Monthly Capacity of 675,000 Pounds of Product)

Million Btu

	At 100 Percent of Capacity		At 5.6 Percent of Capacity	At 20 Percent of Capacity
	US	Soviet	US	Soviet
Light	1,935	1,085	650	362
Comfort Heat	10,700 a/	6,350 a/	4,000	4,762 a/
Electrochemical	752 a/	102 a/	42	20 a/
Process Heat	423	340	24	69
Power	10,300	4,530	577	906
Miscellaneous	743 a/	307 a/	42	102 a/
Run-Up	47,250	23,625	2,580	4,725
Total	[illegible]	[illegible]	[illegible]	10,946

a/ These figures were used in calculating energy requirements for air-frame production (Table [illegible]).

4. The figures given in Table 12 for energy requirements of the hypothetical plant when production is running at 5.6 percent of capacity have been computed for checking against input figures available for total US aircraft engine production in 1947, which is estimated to have been at 5.6 percent of over-all US capacity, according to the following reasoning. Figures for total US aircraft engine production by weight are not available for 1947. Total production as a percentage of total capacity has been calculated on the basis of the average monthly numbers (1,763) and horsepower (1,850,000) of aircraft engines produced in 1947 in comparison with the monthly numbers (24,000) and horsepower (83 million) of those produced at the peak rates reached in 1944. 37/ By numbers the ratio of production in 1947 to production in 1944 is 7.35 percent; by horsepower it is 5.61 percent. Of these two figures for monthly US production of aircraft engines in 1947 as a percentage of 1944 peak production, the figure of 5.61 percent based on horsepower has been chosen for use in checking the energy requirements data for the hypothetical aircraft engine plant against the over-all US data available for 1947. The use of this percentage is open to the objection that the basic data involve a conversion of jet engine take-off thrust (for 1,878 jet engines) to equivalent brake horsepower. A much more serious objection lies, however, against the figure of 7.35 percent based on numbers of engines, which is certainly too high, since the 1944 peak data are mostly for larger engines than those produced in 1947.

5. On the basis that total US aircraft engine production in 1947 amounted to 5.61 percent of capacity, the US energy requirements data for 1947 may be compared with the data synthesized in Table 12 for the hypothetical aircraft engine plant. The US energy requirements data, as shown in Table 13,* amount to about 5.1 billion Btu per month per million square feet of floor space, a figure somewhat below the calculated requirements shown in Table 12 for the hypothetical US plant, operating at 5.6 percent of capacity, which amounts to about 7.9 billion Btu per month per million square feet of floor space. The difference may be in some degree caused by such factors as variations in percentage of spares and average size of engines. It may also, of course, be caused by the method used for estimating the percentage of activity in 1947. As in the case of estimating energy requirements for airframe production, it should be pointed out that much of the floor area available to the US industry at peak war production in 1944 had been retired in 1947 and that it might be more reasonable to base an estimate of the 1947 operating level on the lesser amount of floor space actually available in 1947.

* Table 13 follows on p. 22.

Table 13

Comparative Data on Energy Requirements
for Aircraft Engine Production
Based on Total US Industry in 1947
(Floor Space, 105,315,000 Square Feet)

Type of Energy	Annual Requirements in Physical Units	Annual Requirements Converted (Billion Btu)
Bituminous Coal	127,000 short tons	3,300
Fuel Oil	308,000 bbls	1,620
Gas		
Natural	231,000,000 cu ft	231
Manufactured	395,000,000 cu ft	197
Mixed	9,000,000 cu ft	4
Electricity	334,000,000 kwh	1,140
Total Annual Requirements		6,492
Average Monthly Requirements		541
Average Monthly Requirements per 1 million sq ft		5.137
(Average Monthly Requirements for US Hypothetical Plant at 5.6 Percent of Capacity) a/		(7.915) a/

a. Same figure as used in calculated energy requirements for air-frame production (Table 10).

6. Obviously, the calculations of energy input requirements for aircraft engine production are based on less firm ground than those for airframe production, and they are subject to modification as a result of study now being conducted by ORR.

7. The estimated monthly energy input requirements by use for the hypothetical Soviet aircraft engine plant, presented in Table 12, have been broken down by source of energy, on the same basis as was used in breaking down the requirements for the hypothetical Soviet airframe plant. The results are presented in Table 14.*

8. The data presented in Table 14 have been converted from Btu into the appropriate physical units for each form of energy, and monthly energy input requirements have been computed in these terms per 100,000 pounds of aircraft engine produced. The results, comparable to those presented for airframe production in Table 11a, are presented in Table 14a.**

* Table 14 follows on p. 24.
** Table 14a follows on p. 25.

Table 14

Breakdown by Sources of Monthly Energy Requirements
of Hypothetical Soviet Aircraft Engine Plant
(Estimated Monthly Capacity of 675,000 Pounds of Product)

Million Btu

	Percentage by Source				At 100 Percent of Capacity						At 20 Percent of Capacity				
	Oil	Gas	Coal	Electricity	Oil	Gas	Coal	Electricity	Total	Reduction Factor	Oil	Gas	Coal	Electricity	Total
Light				100	0	0	0	1,085	1,085	1/3	0	0	0	362	362
Comfort Heat	5	11	84		317	692	5,334	0	6,350	3/4	238	524	4,004	0	
Electrochemical				100	0	0	0	102	102	1/5	0	0	0	20	20
Process Heat	14	43	29	14	47	146	100	47	340	1/5	10	29	20	10	69
Power				100	0	0	0	4,530	4,530	1/5	0	0	0	906	906
Miscellaneous	50			50	153	0	0	153	307	1/3	51	0	0	51	302
Run-Up	100				23,625	0	0	0	23,625	1/5	4,725	0	0	0	4,725
Total					24,142	845	5,434	5,917	36,339		5,024	553	4,024	1,349	10,946
Correction for Plant Generation of Electric Power a/					237	0	1,242	1,479			54		283	-337	
Corrected Total					24,379	845	6,676	4,438	36,339		5,078	553	4,307	1,012	10,946

a. The distribution of electric power by sources is estimated as follows: 75 percent is estimated to originate with the electric power grid, and 25 percent to originate in plant generators, of which coal is used to generate an estimated 21 percent and oil to generate an estimated 4 percent.

Table 14a

Breakdown by Sources of Monthly Energy Requirements
of Hypothetical Soviet Aircraft Engine Plant
(Estimated Monthly Capacity of 675,000 Pounds of Product)

	At 100 Percent of Capacity					At 20 Percent of Capacity				
		Gas					Gas			
Monthly Requirements	Oil	Natural	Artificial	Coal	Electrical Power	Oil	Natural	Artificial	Coal	Electrical Power
Total in Million Btu	24,379	845		6,676	4,438	5,078	553		4,307	1,012
	Bbls	Thousand Cu Ft		Short Tons	Thousand Kwh	Bbls	Thousand Cu Ft		Short Tons	Thousand Kwh
Total in Physical Units a/	4,644 b/	758 c/	171 c/	257 d/	1,301 e/	967 b/	496 c/	111.6 c/	166 d/	296.5 e/
Requirements in Physical Units per 100,000 Pounds of Aircraft Engine	688	112.3	25.34	38	192.8	773	367	82.6	123	220

a. For the factor used for conversion from Btu into physical units, see a previously published CIA/RR report. 35/
b. 125,000 Btu per gal, 42 gals per barrel.
c. Based on use ratio natural gas to artificial gas of 4.43; 1,000 Btu per cu ft for natural gas and 500 Btu per cu ft for artificial gas.
d. 13,000 Btu per lb; 2,000 lbs per ton.
e. 3,412 Btu per kwh.

APPENDIX A

EFFECTIVE WORK FACTOR

"Effective work factor" is another term for "productivity" or "efficiency." This factor has been the subject of much dispute in the past. Estimates of its value have been tempered by opinion rather than bolstered by fact. It is hoped to achieve factual support of a final value by breaking "efficiency" into its constituents and evaluating them. This has not yet been seriously attempted, but one bit of pertinent data is at hand. The average horsepower of Soviet machine tools is 7.5; the average horsepower of US tools is 15. If it is assumed that US tools are used at full power (rough cut) for 20 percent of the time (and this assumption invites question), then a Soviet machine, taking a lighter cut for roughing, takes 15 percent longer to machine a given part, or, relative to the US, the USSR is 87 percent as efficient as the US. This holds for the manufacture of engines or other items which are mainly machined. The USSR is 95 percent as efficient as the US in the manufacture of airframes, assuming that the airframes are 20 percent machined.

A study of machine tool maintenance and breakdowns may indicate an additional decrement of efficiency from US practice. This is an item for future study.

APPENDIX B

BILL OF MATERIALS FOR MIG-15 DROP TANK 39/

Table 15

Item	Dimensions	Quantity	Weight (lbs)	Bill of Materials
Bulkhead No. 1	Ellipse 17½" x 16"; 4 x 3½" holes	1	1.5	2.2
Bulkhead No. 2	Circle 20" x 20" radius	1	2.4	2.7
Bulkhead No. 3	U-shape 17½" x 10½" radius	1	1.6	2.9
Bulkhead No. 4	U-shape 17½" x 10" radius	1	1.6	2.9
Bulkhead No. 5	U-shape 16" x 9½" radius	1	1.8	2.4
Bulkhead No. 6	U-shape 14" x 7" radius	1	1.1	1.6
Bulkhead No. 7	U-shape 11" x 4½" radius	1	0.6	0.8
Auxiliary Longeron	15" x 20"	1	2.3	2.5
Main Longeron	80" x 20"	1	9.3	12.8
Skin Top	23" x 70"	1	6.5	11.3
Side, No. 0 - No. 2		1	5.2	6.9
Side, No. 2 - tail		2	22.7	38.2
Rivets	1½" space, 1/8" diameter, 3/16" long	727	0.6	1.1
Nose Cap	6½" diameter	1	0.3	0.4
Filler Cap		1	1.5	3.0
Solder			1.5 (solder)	3.0 (solder)
Nose Rod	¼" diameter, 10" long	1	0.2	0.2
Suspension Rod	3/4" diameter, 19" long	1	2.4	2.4
Suspension Tube	1¼" diameter, 19" long	1	0.6	0.6
Pressure Fitting		2	1.0	1.0
Fuel Outlet		1	1.0	1.0
Seal Strip (Rubber)	1/8" x 1¼" x 140"	1	4.4 (rubber)	4.4 (rubber)
Seat Strip Clips	3/8" x 2"	38	0.2	0.2
Total Steel				97.0
Total Rubber				5.0
Total Solder				3.0
Total			70.3	104.5

APPENDIX C

COMPARISON OF Il-12 AND USAF T-29A

Table 16

	T-29A	Il-12
AMPR Airframe Weight (Lbs)	18,600.0	18,600.0
Weight Empty (Lbs)	28,782.0	
Maximum Take-Off Weight (Lbs)	39,600.0	38,000.0
Span (Ft)	91.8	104.0
Area (Sq Ft)	817.0	1,160.0
Aspect Ratio	10.0	9.3
Root Thick (Percent)	20.0	
Tip Thick (Percent)	15.0	
Length (Ft)	74.7	69.9
Take-Off Power (Brake Hp)	4,800.0	3,650.0
Fuel (Gals)	1,000.0	1,730.0

APPENDIX D

BILL OF MATERIALS FOR USAF T-29A

Table 17

Summary Bill of Materials for T-29A

	Weight (Lbs)
Aluminum	19,678
Aluminum Bronze	3
Brass	15
Copper	846
Magnesium	494
Manganese Bronze	269
Oilite Bronze	1
Phosphor Bronze	1
Paint	
Phenolics	2,390
Plexiglass	171
Rubber	185
Steel	
Alloy	1,438
Stainless	1,663
Carbon	130
Total	[illegible],207

Table 18

Condensed Bill of Materials for T-29A

Materials	Weight (Lbs)
Aluminum	
Bar	556
Castings	342
Extensions	2,689
Coil	1,723
Forgings	905
Plate	90
Sheet	12,483
Tube	364
Wire	526
Total	19,678
Aluminum	
Bronze Bar	3
Brass Bar	3
Screen	½
Sheet	11
Total	17½
Copper Bar	9
Cable	830
Sheet	7
Total	846
Magnesium	200
Casting	
Sheet	276
Extensions	18
Total	494
Manganese	
Bronze Bar	252
	16
Total	268

Materials	Weight (Lbs)
Oilite Bronze	
Bar	1
Phosphor	
Bronze	1
Phenolic Rod	9
Sheet	212
Extension	2,159
Total	2,382
Plexiglass	
Rod	2
Sheet	169
Total	171
Rubber Bar	3
Sponge	1
Extension	93
Foam	29
Hose a/	100
Sheet	59
Total	185
Steel Bar	528
Cable	57
Castings	55
Forgings	192
Sheet	1,988
Plate	49
Strip	12
Tube	276
Wire	50
Total	3,207

a. Size not stated.

APPENDIX E

DATA ON TYPE 31 AND Ju-22/.

1. The following data are available on the Type 31 aircraft. 40/

   a. Span: 185 feet.
   b. Length: 145 feet.
   c. Height: 27 feet.
   d. Gross weight: 225,000 pounds.
   e. Fuel (Diesel): 17,500 gallons.
   f. Bombs: 10,000 pounds.
   g. Nacelles: project 15 feet ahead of the wings, and the airscoop is about halfway out.
   h. Propellers: four-bladed, single rotation, 17-foot diameter.

From the above data, the empty weight of the Type 31 aircraft may be computed as shown in Table 19, which also gives comparative data for the USAF B-29.

Table 19

Computation of Type 31, Empty Weight
(with Comparative Data for B-29)

Weight	Type 31		Lbs B-29
Gross Weight	225,000		140,000
Fuel	101,500 a/		47,700 b/
Bombs	10,000		10,000
Oil	8,500 c/		4,000 c/
Weight, Less Fuel, Bombs, and Oil	105,000		78,500
Crew and Ammunition	7,300	(assumed) d/	7,300
Empty Weight	97,700	(assumed)	71,500

a. Diesel fuel, 17,500 gals at 7 gals per lb.
b. Gasoline.
c. At 1/12 of fuel weight.
d. Assumed to be the same for the Type 31 as for the B-29.

2. The following data are available on the Ju-224 engine.*

a. Length: 11.28 meters.
b. Diameter: 1.63 meters.
c. Scoop to nose: 2.44 meters.
d. Shafts: single rotation.

* Information dated 1946 received from the Air Material Command

APPENDIX F

BILL OF MATERIALS FOR J-48P-5 ENGINE

Table 20

Itemized Bill-of-Materials Weights for J-48P-5 Engine

lbs

Materials	Weight	Materials	Weight
Aluminum		Magnesium	
Bar	32.900	Bar	0.055
Disc	29.700	Casting	652.726
Sheet	13.848		
Tubing	30.823	Nickel	
Casting	775.356	Bar	6.125
Forging	245.819		
		Monel	
Steel		Bar	1.731
Music Wire	0.091		
Wire	0.403	Rubber	
Bar	545.011	Sheet	0.110
Casting AMS 5385	48.699		
Forging	1,685.795	Copper	
Sheet (Mostly Chrome and		Bar	0.179
Chrome-Vanadium)	1,723.078	Sheet	0.025
Tubing	209.918		
		Brass	
Iron		Bar	0.166
Bar	19.299	Sheet	0.316
Casting	136.939	Tubing	0.908
Stainless Steel		Bronze	
Bar AMS 5640,30 32	46.753	Bar	1.941
Wire AMS 5688	0.704	Tubing	4.501
Sheet MAS 5510, 12	7.307		
Tubing AMS 5570	8.944		
Casting AMS 5361	666.217		
Forging AMS 5640	4.264		
Packaging Material: Steel			
(Omitted from Totals)	2,532.086		

Table 21

Summary Total of Bill-of-Materials Weights for J-48P-5 Engine

	Lbs
Aluminum and Alloys	1,128
Steel and Iron	4,369
Stainless Steel	742
Magnesium and Alloys	653
Copper and Alloys	8
Total	6,900
(Finished Weight)	2,725

APPENDIX G

DETAILED DATA ON ENERGY INPUT REQUIREMENTS FOR HYPOTHETICAL AIRFRAME PLANTS

Based on US experience, detailed computations have been made of energy input requirements for the hypothetical airframe plants considered in the text of this report. Both US and Soviet requirements have been computed for this plant, which is assumed to have 1 million square feet of floor area and a maximum capacity to produce 700,000 pounds of airframe per month, using 3 shifts, 8 hours each, 25 (or 26) days a month.* The computations presented below are for production at maximum capacity.

1. Light.

The following expression is used to derive energy inputs for light: Kw = (foot candles) x (area) /(utilization factor) x (maintenance factor) x (lumens per watt) x (1,000)/. For a ceiling height of 40 feet, with a fixture height of 20 feet, a room 90 feet x 200 feet has an index of "B," which gives a utilization factor of the order of 0.70 /1/; a maintenance factor of 0.95 is assumed. A value of 60 lumens per watt is also assumed. The equation then becomes:

Kw = (foot candles) x (area) / (0.70) (0.95) (60) (1,000)

By using this equation, values have been obtained for the various uses of light per hour in the hypothetical US and Soviet airframe plants, as shown in Table 22.**

From the inputs for light in kilowatts per hour given in Table 22, the following values are obtained for kilowatt-hours per month required at 100-percent capacity for the hypothetical airframe plants: 519,000 kwh for the US plant and 290,000 kwh for the Soviet plant.

By using the conversion factor 1 kwh = 3,412 Btu, the following values are obtained for the hypothetical airframe plants:

Input requirements for light at 100 percent of capacity:

US:	1,770,000,000 Btu per month.
Soviet:	990,000,000 Btu per month.

* See above, in text, p. 16

** Table 22 follows on p. 36.

Table 22

Hourly Input Requirements for Light
in Hypothetical US and Soviet Airframe Plants 42/

Use	Foot Candles	Area (Sq Ft)	US (Kw)	Soviet a/
Desk	65	123,000	200	50
Assembly	15	311,000	117	120
Machine	20	52,000	26	25
Fine Machine	100	140,000	350	170
Sheet Metal	20	120,000	61	70
Stores	5	252,000	32	5
Total per Hour x 1.10 b/			865	484

a. Estimated.
b. Standard factor. 43/

2. Comfort Heating.

Use 4 pounds of steam per year per cubic foot of space. 44/ Assume a building height of 40 feet. Volume = 40 million cubic feet. 160 million pounds of steam per year = 13 million pounds per month. Assume water is heated from 40° F to steam at 250° F (no super heat). Take boiler efficiency at 85 percent 45/ and assume (arbitrarily) that pipe loss is 70 percent. Thus the following equation is obtained:

Btu (pounds of steam) x (250-40) (0.85) (1-9.070)

By using the above equation (with 13 million pounds of steam per month), the following values are obtained for the hypothetical airframe plants:

Input requirements for comfort heating at 100 percent of capacity:

US: 10,700,000 Btu per month.
Soviet: 6,350,000 Btu per month.

3. Electrochemical.

Monthly input requirements for electrochemical processes in the hypothetical US and Soviet airframe plants are given in Table 23.

Table 23

Electrochemical Input Requirements per Month For US and Soviet Airframe Plants

Processes	US	Soviet
		Btu
Plating (2 @ 12 v 2,000 amp)	10,236,000	10,236,000
Generator (2 @ 100 kw)	85,300,000	85,300,000
Chargers (3 @ 4 kw)	5,118,000	5,118,000
Rectifier (1 @ 3 kw)	1,279,500	1,279,500
Anodizing a/	650,000,000	0
Total	751,933,500	101,933,500

a. Estimated.

From Table 23 the following values are taken for the hypothetical airframe plants:

Input requirements for electrochemical processes at 100 percent of capacity:

US: 751,933,500 Btu per month.
Soviet: 101,933,500 Btu per month.

4. Process Heat.

For heat-treating dural: assume 60 percent of airframe weight is dural, 10 percent is steel. Dural is taken to 950°F. 46/ For 700,000 pounds of US airframe per month, (700,000) (0.60)/(25) (8) = 2,100 pounds per hour to be treated (assuming all heat treatment to be done in one shift). About 200 kw are required. 47/ For steel, 20 kw, heat-treat (US and Soviet, same). (200 + 20) (25) (8) (3412) [illegible] [illegible] Btu per month.

For welding: assume 10,000 feet of linear weld per month; from 180 amperes at 10 volts on 18-gage steel with 1/8-inch electrode, will run 20 feet per minute on short welds. 48/

$$\frac{(180)\ (10)\ (3412)\ (10{,}000)}{(1{,}000)\ (60)\ (20)} = 51{,}200 \text{ Btu per month.}$$

For soldering and brazing: assume same as welding, 51,200 Btu per month.

For refrigeration: requirements of three $\frac{1}{2}$-horsepower units. 49/ If compressor unit runs 20 percent of time, 25 days per month, three 8-hour shifts:

$$(3)\ (0.5)\ (25)\ (24)\ (0.2)\ (2{,}544) = 460{,}000 \text{ Btu per month.}$$

For forge: the weight ratio of forged material to heat-treated material is about 1,000 to 12,000, or 5/60. 50/ Assuming that forgings are heated to about heat-treat temperature:

$$(163{,}600{,}000)\ (5/60) = 13{,}650{,}000 \text{ Btu per month.}$$

For foundry: the ratio of casting to forging is about 1 to 5: 51/

$$(13{,}650{,}000)\ (1/5) = 2{,}730{,}000 \text{ Btu per month.}$$

By adding together the above figures for heat-treating, welding, soldering and brazing, refrigeration, forge, and foundry, the following total is obtained for the hypothetical airframe plants:

Input requirements for process heat at 100 percent of capacity:

US:	180,559,000 Btu per month.
Soviet:	180,559,000 Btu per month.

5. Power.

Monthly input requirements for power in the hypothetical US and Soviet airframe plants are given in Table 24.* 52/

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* Table 24 follows on p. 39.

Table 24

Monthly Input Requirements of Power for Hypothetical
US and Soviet Airframe Plants a/

Btu.

Machine	US	Soviet	
Hoists 145 @ 1 ton b/	653,000,000	0	(manual)
Cranes 19 @ 1 ton	85,500,000	0	(manual)
Cranes 10 @ 3 tons	125,000,000	0	"
Conveyors 67 @ 5 hp	106,630,500	0	"
Monorail 1 @ 3 hp	954,000	0	"
Vacuum Sweeper 8 @ 3/4 hp	1,910,000	0	"
Hand Tools 5,000 @ 1/5 hp c/	318,000,000	0	"
Brakes 30 @ 5 hp c/	101,000,000	0	"
Routers 6 @ 5 hp c/	9,520,000	0	"
Boring Machines 2 @ 6 hp	3,810,000	3,810,000	
Broaches 6 @ 5 hp	7,940,000	0	
Drill Presses 141 @ 1 hp	44,850,000	44,850,000	
Grinders 124 @ 1 hp	39,400,000	39,400,000	
Lathes 107 @ 5 hp	170,000,000	170,000,000	
Millers 85 @ 5 hp	136,000,000	136,000,000	
Planers 1 @ 5 hp	1,600,000	1,600,000	
Misc. 200 Units @ 5 hp	318,000,000	160,000,000	
Presses 60 @ 10 hp	191,000,000	100,000,000	
Shears, Punches 70 amp 5 hp	112,000,000	0	(manual)
Forges 6 @ 5 hp	9,500,000	9,500,000	
Riveters 100 @ 2 hp	63,600,000	0	(manual)
Total, 1 Shift	2,499,214,500	665,160,000	
Total, 3 Shifts d/	5,500,000,000	1,460,000,000	

a. 50 percent utilization assumed for all machine tools.

b. Assume 2,000 lbs lifted 50 ft in 10 secs = 10,000 ft-lb/sec = 772 Btu/min. Use 90 percent efficiency and 50 percent utilization: per ton of capacity, (772/0.9) (8/2) (60) (25) = 4,500,000 Btu per month. The lifting speed is high, but power used by trolley and bridge motors has been neglected.

c. Estimated.

d. 2.2 = shift ratios 100-70-50.

From Table 24, the following values are taken for the hypothetical airframe plants:

Input requirements for power at 100 percent of capacity:

US:	5,500,000,000 Btu per month.
Soviet:	1,460,000,000 Btu per month.

6. Miscellaneous.

Monthly input requirements for energy for miscellaneous purposes in the hypothetical US and Soviet airframe plants are given in Table 25, on the basis of US experience. 53/

Table 25

Monthly Energy Requirements for Miscellaneous Purposes for Hypothetical US and Soviet Airframe Plants

Btu

Item	US	Soviet
Rectifiers 3 @ 24 v 130 amp	3,992,040	1,000,000
Dust Collector 1 @ 5 hp	1,590,000	0
Air Compressor 2 @ 5 hp	3,180,000	3,180,000
Vacuum Pump 1 @ 1 hp	318,000	0
Drug Scrubber 2 @ 3/4 hp	477,000	0
Spray Guns 17 @ 1 hp	5,410,000	0
Dryer 1 @ 3/4 hp	239,000	0
Blueprinter 15 @ 1 hp	4,770,000	2,000,000
Tensile Tester 1 @ 2 hp	636,000	636,000
Vent Duct Tester 1 @ 7½ hp	2,390,000	0
Autos and Trucks a/	720,000,000	300,000,000
Total	743,002,040	306,816,000

a. Using 100 vehicles, at 60 gals per engine per month, 6 lbs per gal, and 20,000 Btu per lb.

From Table 25, the following values are taken for the hypothetical air-frame plants:

Input requirements for energy for miscellaneous purposes at 100 percent of capacity:

US:	743,002,040 Btu per month.
Soviet:	306,816,000 Btu per month.

7. Run-Up Fuel.

Run-up fuel is calculated at 2,000 horsepower per engine for 2 hours, 1 pound of fuel per horsepower-hour and 20,000 Btu per pound, for 25 aircraft per month:

$$(25)\ (2{,}000)\ (2)\ (1.0)\ (20{,}000) = 2 \text{ billion Btu per month.}$$

The Soviet plant requirements are assumed to be one-half the US plant requirements.

The following values are used for the hypothetical airframe plants:

Input requirements for run-up fuel at 100 percent of capacity:

US:	2,000,000,000 Btu per month.
Soviet:	1,000,000,000 Btu per month.

APPENDIX H

Table 26

Interchangeability of Energy Sources in Aircraft Production

Requirements	Oil	Gas	Coal	Peat	Wood	Electricity	Steam	Manpower
Light								
Comfort Heat	x	x	x	x	x			
Electrochemical								
Plating						x		
Anodizing								
Battery Charging								
Process Heat								
Heat Treating	x	x	x					
Welding		x				x		
Soldering	x	x				x		
Brazing	x	x	x			x		
Explosive								
Riveting						x		
Refrigeration		x				x		
Foundry	x	x	x			x		
Power								
Forming								
Shears						x		x
Brake						x		x
Rolls						x		x
Router						x		x
Drop Hammer						x	x	x
Sheet Stretchers						x	x	x
Punch Press						x		x
Press						x	x	
Pipe Benders						x		x
Lathes						x		
Milling Machines						x		
Shapers								
Planers								
Drill Presses								
Small Drills						x		x
Nibblers						x		
Joining								
Nut Runners						x		x
Screw Drivers						x		x
Riveters						x		x
Head Millers						x		x
Finishing								
Shot Peening						x		x
Sand Blasting						x		x
Painting						x		x
Transporting								
Cranes						x		x
Carts						x		x

APPENDIX I

DATA FOR ANALYZING THE USE OF ENERGY BY SOURCE IN THE AVIATION INDUSTRIES OF THE USSR AND CZECHOSLOVAKIA

Examination of a partial survey of Soviet and Czechoslovakian aircraft plant data for information on their use of different sources of energy indicates that, of the 40 plants so far examined, there are no data on 13, or about a third (32 percent). Of the remaining 27 plants, electric power comes into the plant from outside in 18 cases, is internally generated by coal in 3 cases, by diesel in 1, and by unstated means (probably coal) in 2 cases. Comfort heat seems to be supplied by coal in 16 cases, oil in 1 case, gas in 2 cases. In nine cases there is no indication. Process heat is obtained from coal in two cases, gas in three cases, oil in one case, electricity in one case.

On the basis of the above fragmentary data, the following uses have been assumed in Table 27.

Table 27

Tentative Breakdown of Uses of Energy by Source in Soviet and Czechoslovakian Aircraft Plants

Percent

Use	Power Source			
	Electric Grids	Coal	Gas	Oil
Electric Power	75	21	0	4
Process Heat	14	29	43	14
Comfort Heat	0	84	11	5

The incomplete data on which the above summary is based are presented in Table 28.*

* Table 28 follows on p. 44.

Table 28

Data Available on the Use of Energy by Sources in Aircraft Plants in the USSR and Czechoslovakia

Town	Plant	Data
Central Region		
Tbilisi	No. 31	Coal, oil, and electric process furnace. Central heating by coal. Electricity from local grid, with own standby plant.
Gor'kiy	No. 21	Electricity from city grid. Coal heat.
Moscow (Khimki)	No. 301	Electricity from outside of plant. Coal heat.
Eastern Region		
Novosibirsk	No. 153	Electricity from city grid.
Omsk	No. 166	Electricity from city grid.
Tashkent	No. 84A	Electricity.
Tashkent	No. 84B	Electricity from city grid.
Irkutsk	No. 39	Coal-fired plant supplied power to plant and town.
Ulan-Ude	No. 99	Electricity from city grid. Had standby plant.
Komsomol'sk	No. 126	One power plant, coal-fired.
Komsomol'sk	No. 130	Electricity from city grid.
Semenovka	No. 116	Electricity from city grid. Had standby plant.
Krasnoyarsk		Own power plant.

Table 28

Data Available on the Use of Energy by Sources in Aircraft Plants
in the USSR and Czechoslovakia
(Continued)

Town	Plant	Data
Western Region		
Archangel		No report.
Gatchina		No report.
Kargopol'		Has own power station (heating).
Leningrad	No. 162	No report.
Leningrad	No. 381	No report.
Leningrad	No. 211	No report.
Leningrad	No. 330	No report.
Leningrad	No. 7	(Engine parts) electricity from city grid. Heating plant uses from 10 to 100 tons of coal per day (reports vary). Probably 10 tons to comfort heat and process steam, 60 tons to forges, etc. Floor area 156,400 sq. ft.
Leningrad	Nos. 23, 272	Electricity from city grid. Heat from coal (wood) boiler house, not often used.
Leningrad	No. 448	Electricity from city grid. Central heating plant, uses coal and "oilstone." Gas from city mains in all parts of plant.
[illegible]	No. 135	Electricity from city gird. Central heating by oil-fired plant.

Table 28

Data Available on the Use of Energy by Sources in Aircraft Plants
in the USSR and Czechoslovakia

Town	Plant	Data
Khar'kov		No report.
Kaliningrad	"Junkers"	No report.
Kaunas, Lithuanian SSR		No report.
Minsk	"Arado"	No report.
Narva, Estonian SSR		No report.
Riga, Latvian SSR		Gas from city mains, for heat-treat. Diesel-generated electric power. No mention of comfort heating.
Leningrad	"Krasnyy Parus"	Power from city grid.
Volkhovstroy		Electricity from city grid.
<u>Czechoslovakia</u>		
Otrokovice	Motorcar Works, National Corporation, Otrokovice Plant	No report.
Prague	Aviation Works, National Corporation, Vysocany Plant (AERO)	Electricity from city grids. Coal heating.
Uherské Hradiště	Motorcar Works, National Corporation, (new Avia plant)	Coal heating.
Prague	Motorcar Works, National Corporation, Avia Cakovice Plant	Electricity from city grids. Coal heating, 2 wagons per week.

Table [illegible]

Data Available on the Use of Energy by Sources in Aircraft Plants
In the USSR and Czechoslovakia
(Continued)

Town	Plant	Data
Uherské Hradiště	Motorcar Works, National Corporation, (Old Avia plant)	Coal heating.
Choceň	Motorcar Works, National Corporation, Choceň Plant (Kraz-Benes)	Coal heating.
Prague	Aviation Works, National Corporation, Letňany Plant (Letov-Smolský)	Generates own electricity, uses coal for heat.
Prague	Praga	Electricity and gas from city. Standby electric plant. Gas heating.

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APPENDIX D

DETAILED DATA ON ENERGY REQUIREMENTS FOR HYPOTHETICAL AIRCRAFT ENGINE PLANTS

Based on US experience, detailed computations have been made of energy requirements for the hypothetical aircraft engine plants considered in the text of this report. Both US and Soviet requirements have been computed for this plant, which is assumed to have 1 million square feet of floor space and a maximum capacity to produce 675,000 pounds of aircraft engines per month, using 3 shifts, 8 hours each, 25 (or 26) days a month. The figures presented below are for production at maximum capacity. Certain figures have been taken, as indicated below, directly from the figures computed for the hypothetical airframe plants (presented in Appendix C).

1. Light.

By the same method used above (in Appendix C) in computing input requirments for light in the hypothetical airframe plants, values have been obtained for the various uses of light per hour in the hypothetical aircraft engine plants as shown in Table 29.

Table 29

Hourly Input Requirements for Light in US and Soviet Aircraft Engine Plants (Plant Area 4,727,000 sq. ft.)

Use	Foot Candles	Area (Sq. Ft.)	US (Kw)	Soviet (Kw)
Machining	65	1,0[illegible],6[illegible]2	1,680	1,600
Inspection	100	303,345	760	700
Assembly	33	239,792	39	90
Test	35	93,566	37	18
Plant Maintenance	15	151,702	91	15
Tool Cribs	20	65,349	67	60
Master Mechanics	60	380,673	433	200
Materials	15	623,950	373	37
Service	15	16,7[illegible]	10	[illegible]
Building Utilities	15	[illegible]	335	35
Offices	[illegible]	[illegible]	265	230
Aisles	[illegible]	797,065	199	20
Other	[illegible]	[illegible]	121	10
Total			4,463	2,93[illegible]

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APPENDIX [illegible]

DETAILED DATA ON ENERGY REQUIREMENTS OF HYPOTHETICAL AIRCRAFT ENGINE PLANTS

Based on US experience, detailed computations have been made of energy requirements for the hypothetical aircraft engine plants considered in the text of this report. Both US and Soviet requirements have been computed for this plant, which is assumed to have 1 million square feet of floor space and a maximum capacity to produce 675,000 pounds of aircraft engines per month, using 3 shifts, 8 hours each, 25 (or 26) days a month. The figures presented below are for production at maximum capacity. Certain figures have been taken, as indicated below, directly from the figures computed for the hypothetical airframe plants (presented in Appendix G).

1. Light.

By the same method used above (in Appendix G) in computing input requirements for light in the hypothetical airframe plants, values have been obtained for the various uses of light per hour in the hypothetical aircraft engine plants as shown in Table 29.

Table 29

Hourly Input Requirements for Light in US and Soviet Aircraft Engine Plants (Plant Area 4,727,000 sq. ft.)

Use	Foot Candles	Area (Sq. Ft.)	US (Kw)	Soviet (Kw)
Machining	65	[illegible]	1,580	1,600
Inspection	100	[illegible]	760	700
Assembly	[illegible]	[illegible]	89	90
Test	25	[illegible]	37	18
Plant Maintenance	15	[illegible]	91	15
Tool Cribs	20	[illegible]	67	60
Master Mechanics	60	180,673	433	200
Materials	15	621,950	373	37
Service	15	[illegible]	[illegible]	5
Welfare Facilities	[illegible]	[illegible]	[illegible]	35
Offices	[illegible]	[illegible]	265	230
Aisles	[illegible]	[illegible]	199	[illegible]
Garage	[illegible]	[illegible]	121	10
Total			4,463	2,92[illegible]

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From the inputs for light in kilowatts per hour given in Table 22, the following values are obtained for kwh per month required at 100-percent capacity for the hypothetical aircraft engine plants (area: 1 million square feet): 567,000 kwh for the US plant and 370,000 kwh for the Soviet plant.

By using the conversion factor 1 kwh = 3,412 Btu, the following values are obtained for the hypothetical aircraft engine plants:

Input requirements for light at 100 percent of capacity:

US:	1,935,000,000 Btu per month.
Soviet:	1,085,000,000 Btu per month.

2. Comfort Heating.

The requirements for comfort heating are the same in the hypothetical aircraft engine plants as in the hypothetical airframe plants (in Appendix G) as follows:

Input requirements for comfort heating at 100 percent of capacity:

US:	10,700,000,000 Btu per month.
Soviet:	6,350,000,000 Btu per month.

3. Electrochemical.

Requirements for electrochemical processes in the hypothetical US and Soviet aircraft engine plants are taken to be the same as for the hypothetical airframe plants (in Appendix G) as follows:

Input requirements for electrochemical processes at 100 percent of capacity:

US:	751,933,500 Btu per month.
Soviet:	101.933,500 Btu per month.

4. Process Heat.

For heat-treating, by using the same method as used above (in Appendix G) for the hypothetical airframe plants, the input requirements obtained come to about 65 million Btu per month for the hypothetical aircraft engine plants, at 100 percent of capacity.

Welding and soldering input requirements for the hypothetical aircraft engine plants are assumed to be roughly double those of the airframe plnts (given in Appendix G), or about 200,000 Btu per month.

There are no requirements for refrigeration in the aircraft engine plants.

For forge and foundry the J-48 bill of materials has been used. There are 4,216 pounds of forged and cast items per engine, or (254) (4,216) = 1,070,000 pounds per month. The weight of forged and cast items in the hypothetical airframe plant (Appendix G) was (0.70) (700,000) (0.1) = 49,000 pounds per month. Requirements for this weight were 16,380,000 Btu per month. To obtain requirements for the hypothetical aircraft engine plants:

(1,070,000/49,000) (16,380,000) = 357,575,400 Btu per month.

By adding together the above figures for US requirements for heat-treating, welding and soldering, and forge and foundry, the following total is obtained for the hypothetical aircraft engine plant and an estimate made for the corresponding Soviet plant:

Input requirements for process heat at 100 percent of capacity:

US:	422,775,400 Btu per month.
Soviet:	340,000,000 Btu per month.

9. Power.

Monthly input requirements for power in the hypothetical US and Soviet aircraft engine plant are given in Table 30

Table 30

Hourly Input Requirements of Power
for US Aircraft Engine Plant
(Plant Area: 4,727,000 Sq. Ft.)

Machine	US		
	Number of Machines	Hp per Machine	Hp per Hour
Boring	460	15	6,900
Broach	64	15	960
Drill	375	15	5,625
Gear Cutter	124	15	1,860
Grinders	640	15	9,600
Lathes	640	15	9,600
Millers	430	15	6,450
Miscellaneous	520	15	7,800
Rolls	17	15	255
Presses			
Vertical, Hydraulic, 150-Ton Average	42	17.5	735
Vertical, Mechanical, 65-Ton Average	39	17.5	682.5
Punch and Shears	30 @ 15 hp for US		450
Forging Hammers	[illegible]	"	15
Riveting Machines	[illegible]	"	90
Thread Rollers	24	"	360
Total Hp			51,382.5

In a comparable Soviet plant the number of machines is estimated to run at 3,000, or about the same as in the US plant, with the exception of certain items (rolls, riveting machines, and thread rollers) of which the Soviet plant is assumed to have none. The Soviet machines are assumed to be of 7.5 horsepower (see Appendix A), as against 15 horsepower for the US machines. The power requirements of a comparable Soviet plant would thus amount to (3,000) (7.5) = 22,500 horsepower per hour.

For 3 shifts, 26 days per month, assume a 60 percent utilization factor. For the hypothetical aircraft engine plants, with an area of 1 million square feet, converting at 2,545 Btu per horsepower-hour (26) (24) (0.60) (2,545) (hp)/(4.727) = Btu per month. Using this equation and the values in Table 30, the following values are obtained for the hypothetical aircraft engine plants:

Input requirements for power at 100 percent of capacity:

US:	10,300,000,000 Btu per month.
Soviet:	4,530,000,000 Btu per month.

6. Miscellaneous.

Monthly input requirements for energy for miscellaneous purposes are taken to be the same as for the hypothetical airframe plants (in Appendix G), as follows, at 100-percent capacity:

US:	743,002,040 Btu per month.
Soviet:	306,816,000 Btu per month.

7. Run-Up Fuel.

US requirements at 1,500 horsepower per engine for 5 hours green run and 4 hours final run, 250 engines per month, 0.7 pound per horsepower, and 20,000 Btu per pound:

(1,500) (9) (250) (0.7) (20,000) = 47,250,000,000 Btu per month.

No allowance is made for reclamation of energy. The Soviet plant requirements are assumed to be about one-half the US plant requirements.

The following values are used for the hypothetical aircraft engine plants.

Input requirements for run-up fuel at 100 percent of capacity:

US:	47,250,000,000 Btu per month.
Soviet:	23,625,000,000 Btu per month.

APPENDIX F.

GAPS IN INTELLIGENCE

There is almost no information available on the input requirements of the aviation industry of the USSR. Observation has provided good estimates of the salient characteristics of many Soviet aircraft, but there are very few aircraft, most of them obsolescent, available for detailed analysis. On recent Soviet production methods there is virtually no direct evidence of a quantitative character. The state of information in this field is still substantially the same as described in CIA/RR PR-8, Input Requirements of the Aviation Industry of the USSR, 29 October 1951. TOP SECRET.

APPENDIX L

METHODOLOGY

This entire report is an exercise in methodology -- specifically, in the development of US analogous factors applicable to the study of input requirements in the aviation industry of the USSR. In developing analogous factors for the study of each of the types of input requirements dealt with in this report -- manpower, material, and energy -- the methods used have been derived from and tested against US (and UK) experience. The application of these methods to the aviation industry of the USSR involves a large element of judgment, and the resulting estimates of Soviet input requirements are at best illustrative of the general order of magnitude of the Soviet requirements. As indicated below in Appendixes L and M, the kind and extent of information available on the aviation industry of the USSR precludes its being used at the present time to cross-check estimates based on US analogy of Soviet input requirements in this industry.

APPENDIX [illegible]

SOURCES AND EVALUATION OF SOURCES

1. Evaluation of Sources.

Most of the sources used and cited in this report deal with the US aviation industry. They are considered to be highly reliable. Data on Soviet aircraft are all admittedly tentative and incomplete. Data on Soviet plants and production are fragmentary and inconclusive.

2. Sources.

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43. Ibid.
44. Ibid., Table 28, p. 1,631.
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48. Ibid., Table 2, p. 1,726, Table 4, p. 1,728.
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51. CIA/RR PR-8, cited above, p. 19.
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PROVISIONAL INTELLIGENCE REPORT

COMPUTATION OF INPUT REQUIREMENTS OF THE AIRCRAFT INDUSTRY OF THE USSR

CIA/RR PR-19

October 1952

ANNEX

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS FOR MIG-15 AIRFRAME AND LANDING GEAR

Note

The data and conclusions contained in this report do not necessarily represent the final position of ORR and should be regarded as provisional only and subject to revision. Additional data or comments which may be available to the user are solicited.

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CENTRAL INTELLIGENCE AGENCY

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ANNEX

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS FOR MIG-15 AIRFRAME AND LANDING GEAR

Pounds

Item	Number of Pieces	Finished Dural	Finished Steel	Finished Total	Bill of Materials Dural	Bill of Materials Steel	Bill of Materials Total
A. **Wing Group.**							
Wing							
Front Spar, O.B.							
Web, Dural Sheet .057 x 8-3/4 x 114 (10 in. x 3 in. hole)	1	4.3			6.3		
Cap, Dural Sheet .080 x 2 x 114	1	1.8			1.8		
Rivets, 3/16 @ 3/in.	350	0.3			0.6		
Front Spar, I.B. (E-E)							
Web, Dural Sheet .113 x 7 x 139 (75-ST)	1	9.7			9.7		
Cap, Alcoa 79-T x 139 in.	2	8.3			8.3		
Cap, Zee .265 in x 2¼ in. x 139 in.	2	16.7			16.7		
Rivets, 3/16 @ 3/in.	840	0.8			1.5		
Rear Spar, O.B.							
Web, Dural Sheet .0975 x 5-7/8 x 133 (11 in. x 3 in. holes)	1	7.5			11.0		
Cap, Dural Sheet .093 x 2 x 133 (75-ST)	1	2.7			2.7		
Cap, Dural Sheet .067 x 1 x 133 (75-ST)	1	0.9			0.9		
Cap, Dural Sheet .067 x 1½ x 133	1	1.4			1.4		
Rivets, 3/16 @ 3/in.	400	0.4			0.7		
Rear Spar, I.B.							
Web, Dural Sheet .0975 x 8¼ x 84	1	6.9			6.9		
Cap, Dural Sheet .093 x 3 x 84	1	2.4			2.7		
Cap, Dural Sheet .067 x 2 x 84 (75-ST)	1	1.2			1.3		
Cap, Dural Sheet .067 x 1½ x 84 (75-ST)	1	0.9			0.9		
Rivets, 3/16 @ 3/in.	250	0.2			0.5		
Diagonal Spar							
Web, Dural Sheet .080 x 5½ x 63	2	5.6			6.5		
Caps, Steel "T" Stock: 3½ x 2½ x 63	2		103.0			306.0	
Bolts, @ 3/4 in Pitch, 3/8 in. ø x 2 in. lg	170		8.5			17.0	

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS FOR MIG-15 AIRFRAME AND LANDING GEAR
(Continued)

Item	Number of Pieces	Finished (Pounds) Dural	Finished Steel	Finished Total	Bill of Materials Dural	Bill of Materials Steel	Bill of Materials Total
Nuts, 3/8 in. (Staked)	170		6.8			6.8	
Drag Strut							
Web, Dural .080 x 6-3/4 x 41.5	1	2.3			2.3		
Caps, .063 x 2½ x 41.5	1	0.7			0.7		
Rivets, 3/16 in. ∅ @ 3/in	250	0.2			0.5		
Cap, Dural .31 x 1-3/4 x 41.5	1	2.2			2.2		
Struts, Alcoa 79-KE x 10	3	0.7			0.7		
Rivets, 3/16 in. ∅ @ 2/in.	60	0.1			0.1		
Drag Strut							
.094 x 2½ x 41.5	1	1.0			1.0		
False Spar (I.B. fwd)							
Cap, Top, .11 x 2¼ x 24 in.	2	1.1			1.1		
Cap, Lower, .11 x 2¼ x 11 in.	2	0.5			0.5		
False Spar (Aileron Hinge)							
Cap, Sheet Section, Similar to Alcoa 22022 x 60 in.	1	2.2			2.2		
Drag Rib							
Caps, .125 x 2½ x 29 in.	2	1.7			1.7		
Web, Dural .037 x 9 in. x 68 in.	1	1.7			2.3		
Rivets, 1/8 in. ∅ @ 3/in. (Skin Included)	900	0.2			0.6		
Stringers, Leading Edge I.B. (Extruded Sections; Closest US Shape Is Quoted)							
1 Alcoa 10135 - 1003 x 76	1	1.2			1.2		
2 Alcoa 10135 - 1003 x 97 in.	1	1.6			1.6		
3 Alcoa 10135 - 149 in.	1	1.1			1.1		
4 Alcoa 10135 - 0601 135 in.	1	1.0			1.0		
5 Alcoa 10135 - 0601 97 in.	1	0.7			0.7		
Stringers, Leading Edge, O.B.							
1 .094 x 1½ x 38 in.	1	0.5			0.5		
2 .094 x 1½ x 98 in.	1	1.3			1.3		
3 .094 x 1½ x 48 in.	1	0.6			0.6		
4 .094 x 1½ x 59 in.	1	0.8			0.8		
5 .094 x 1½ x 98 in.	1	1.2			1.2		
Rivets, 1/8 in @ 3/in. (Skin)	2700	0.7			1.4		

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS
FOR MIG-15 AIRFRAME AND LANDING GEAR
(Continued)

Pounds

Item	Number of Pieces	Finished Dural	Finished Steel	Finished Total	Bill of Materials Dural	Bill of Materials Steel	Bill of Materials Total
Stringers, between Spars							
6 Alcoa 10135 - 0601 x 64	2	0.9			0.9		
7 Alcoa 10135 - 0601 x 119	2	1.8			1.8		
8 Alcoa 10135 - 0601 x 52	2	0.8			0.8		
6 .06 x 1¼ x 54	2	0.5			0.5		
8 .06 x 1¼ x 70	2	1.0			1.0		
Ribs, (Counting Flap and Aileron Ribs Twice)							
Dural Sheet, .037 x 8½ x 62 (3 x 3 in. ϕ Holes, ½ Flange All Around)	9	25.0			37.0		
Rib Clips, .06 x 1½ x 7 in	36	2.2			2.2		
Rivets, 1/8 in @ 3/in. (Includes Skin)	5100	1.3			2.6		
Skin							
Root I.B., .074 x 42 x 27 Skin (Upper)	1	8.5			9.5		
Root I.B., .100 x 42 x 27 Doubler (Upper)	1	11.7			14.5		
Root I.B., .066 x 33 x 36 Skin (Upper and Lower)	2	16.0			29.2		
Root I.B., .100 x 33 x 36 Doubler (Upper and Lower)	2	23.8			43.6		
L.E. Inboard, .072 x 50 x 102	1	25.0			38.2		
L.E. O.B., .055 x 50 x 102	1	24.2			28.6		
Between Spars, .054 x 30 x 125 (Upper and Lower)	2	31.4			42.0		
T.E. Inboard (Upper), .054 x 20 x 115	1	12.1			12.9		
Rivets (Along Spars), .054 x 20 x 115	1	12.1			12.9		
Rivets (Along Spars), 1/8 @ 3/in.	3000	1.0			2.0		
Wing Tip, .054 x 24 x 60	1	5.8			12.0		
Wing Connector							
.125 x 2½ x 57"	1	3.5			3.5		
Aileron Hinge Fittings							
Steel .063 x 6 x 4	2						
.063 x 6 x 2	4						
.063 x 2 x 2	4						
.063 x 3 x 2	2						
Total		1.8			1.8		

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS FOR MIG-15 AIRFRAME AND LANDING GEAR
(Continued)

Pounds

Item	Number of Pieces	Finished Dural	Finished Steel	Finished Total	Bill of Materials Dural	Bill of Materials Steel	Bill of Materials Total
Flap Hinge Fittings			1.8			1.8	
Spoiler Hinge Fittings			1.8			1.8	
Wing Weights	1		65.0			65.0	
Handhole Cover, Alcoa 23787 x 72	1	1.9			1.9		
Aileron Differential Bracket (est.)	1	5.0			5.0		
L.G. Hinge Fitting (est.)	1		25.0			35.0	
Fence (est.)	1	5.0			6.0		
Wing Panel, Total	-	317.8	213.7	531.5	416.3	435.2	851.5
Flap							
Bottom Skin, .040 x 19 x 107	1	8.1			8.6		
Top Skin, .037 x 20 x 107	1	8.6			9.2		
Nose Skin, .040 x 2 x 107	1	0.9			1.0		
Trail Edge, .060 x 2 x 107	1	1.3			1.3		
Ribs, .040 x 4 x 19 (See Wing)	11	1.9			3.3		
Rivets, 1/8 in. @ 2/in.	2350	0.7			1.4		
Flap Hinge Fittings	2		1.8			1.8	
Spar, .040 x 4 x 107	1	1.7			1.7		
Total		23.2	1.8	25.0	26.5	1.8	28.3
Aileron							
Spar, .040 x 6 x 60	1	1.4			1.4		
Tail Edge, .060 x 2 x 67	1	0.8			0.8		
Ribs, .037 x 6 x 18 (See Wing)	2	0.8			1.5		
Skin .054 x 18 x 63	2	11.4			12.4		
Hinges	2		1.8			1.8	
Rivets (See Flap)		0.4			0.8		
Total		14.8	1.8	16.6	16.9	1.8	18.7
Wing Carry-through Structure							
Front, .23 x 8 x 52 in.	1	13.3			13.3		
Fittings, Steel	2		5.0			10.0	
Rear, Cap Steel T (See Wing) x 56 in.	2		91.4			272.0	
Web, Dural .080 x 5 x 52	2	42.0			42.0		
Bolts (See Wing)			8.5			17.0	
Nuts			6.8			6.8	
Total		55.3	111.7	167.0	55.3	305.8	361.1

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS FOR MIG-15 AIRFRAME AND LANDING GEAR (Continued)

Item	Number of Pieces	Finished Dural	Finished Steel	Finished Total	Bill of Materials (Pounds) Dural	Bill of Materials (Pounds) Steel	Bill of Materials (Pounds) Total
Total Wing (Two Wings Plus Carry-through)		766.9	546.3	1313.2	948.9	1183.4	2132.3
Spoilers		4.6			4.6		
Total Wing Group		771.5	546.3	1317.8	953.5	1183.4	12136.9
B. Tail Group.							
Fin							
Spar Cap Tee, 2 x 3 x 3/8 x 97 in.	2		99.4			345.0	
Webs, Dural, .080 x 7 x 97 (75-ST)	2	11.0			16.0		
Lead Edge,							
.0465 x 10 x 142	2	7.1			8.5		
.0465 x 4 x 142	2	2.8			3.3		
Bolts, @ 3/4 in. Pitch 3/8 in. ø x 1 in. lg.	380		32.0			38.0	
Nuts, 3/8 in.	380		11.4			11.4	
Trail Edge, .054 x 4 x 112	1	2.2			2.2		
Stringers, Alcoa							
10135 - 1003 x 125 in.	2	4.1			4.1		
10135 - 1003 x 122 in.	2	3.9			3.9		
10135 - 1003 x 117 in.	2	3.7			3.7		
Ribs, .037 x 6 x 36 (3 x 3 in. ø holes)	10	7.2			10.1		
Ribs Clips, .06 x 2 x 6 in.	20	1.5			1.5		
Fuselage Attach, .125 x 2¼ x 82 in.	2	4.4			4.4		
Hinge Brackets, .065 x 4 x 3	4						
.065 x 4 x 2	8						
.065 x 2 x 2	8						
.065 x 2 x 2	4	2.9			2.9		
Skin, .047 x 57 in. x 36	2	19.7			28.6		
.037 x 24 x 47	2	8.6			21.1		
Rivets, 1/8 in. ø @ 2/in.	2350	1.1			1.4		
Total		80.2	142.8	223.0	111.7	394.4	506.1
Rudder							
Spar, .054 x 4 x 112	1	2.2			3.3		
Trail Edge, .060 x 2 x 24	1	0.3			0.3		
Tab, .046 x 1 x 40	1	0.2			0.2		
Ribs, .034 x 4 x 18	12	2.3			3.8		
Rib Clips, Alcoa 79-M x 6 in.	12	0.9			0.9		

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS
FOR MIG-15 AIRFRAME AND LANDING GEAR
(Continued)

Pounds

Item	Number of Pieces	Finished Dural	Finished Steel	Finished Total	Bill of Materials Dural	Bill of Materials Steel	Bill of Materials Total
Skin, .036 x 18 x 36	2	5.2			5.8		
.036 x 18 x 51	2	7.4			8.2		
Hinge Brackets (magnesium alloy)	4	(1.0 magnesium alloy)*			(1.0 magnesium alloy)		
Horn .065 Wall x 3 in. O.D. x 24 in.	1		4.1			4.1	
Rivets, 1/8 in. ∅ @ 2/in.	1440	0.6			1.0		
Total Frame of Rudder		19.1	4.1		23.5	4.1	
Static Balance, @ 70%			17.0			17.0	
Total		19.1	21.1	41.2	23.5	21.1	45.6
Stabilizer (One Side)							
Spar, Inboard, I beam, 55 in. lg 11 x 2 in. ∅ Holes	1		35.0			217.0	
Spar, Outboard, Channel .064 x 6 x 36	1		3.9			4.2	
Spar, Trail Edge, Dural .054 x 4 x 75	1	1.5			1.5		
Ribs, .046 x 4 x 25	7	3.2			5.4		
Rib Clips, .06 x 2 x 1½	30	0.5			0.5		
Skin, .040 x 25 x 80	2	16.0			23.5		
Stringers, .06 x 1¼ x 57	2	0.8			0.8		
.06 x 1¼ x 62	2	0.8			0.8		
.06 x 1¼ x 40	2	0.5			0.5		
Hinge Bracket .065 x 4 x 3	2						
.065 x 4 x 2	4						
.065 x 2 x 2	6		1.5			1.5	
Total		23.3	40.4	63.7	33.0	222.7	255.7
Elevator (One Side)							
Spar, .054 x 4 x 75	1	1.5			1.7		
Trail Edge, .060 x 2 x 42	1	0.5			0.5		
Ribs, .046 x 3 x 11	7	1.3			2.2		
Rib Clips, .06 x 2 x 5/8	7	0.1			0.1		
Skin, .040 x 11 x 70	2	6.2			8.6		
Hinge Brackets (See Stabilizer)			1.5			1.5	
Horn 3 in. OD x .065 Wall x 10 in.	1		2.0			2.0	
Rivets 1/8 in. @ 2/in.	780	0.3			0.5		
Total Frame of One Elevator		9.9	3.5		13.6	3.5	

* All paranthetical entries are excluded from dural and steel totals but appear in the over-all totals.

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS
FOR MIG-15 AIRFRAME AND LANDING GEAR
(Continued)

Item	Number of Pieces	Finished Dural	Finished Steel	Finished Total	Bill of Materials Dural	Bill of Materials Steel	Bill of Materials Total (Pounds)
Static Balance @ 70%			9.4			9.4	
Total		9.9	12.9	22.8	13.6	12.9	26.4
Total Tail Group		165.7	270.5	437.2	228.2	886.7	1115.9
C. Body Group.							
Longerons, Alcoa 12061 x 310 in.	6	91.8			91.8		
12061 x 154 in.	2	15.2			15.2		
12061 x 72 in.	2	7.1			7.1		
12061 x 260 in.	2	25.5			25.5		
Alcoa 10135 - 0601 x 156 in.	2	6.6			6.6		
Dural .065 x 4 x 156	4	16.5			16.5		
Stringers, Alcoa 10135 - 0601 x 124	2	1.9			1.9		
10135 - 0601 x 166	2	2.5			2.5		
10135 - 0601 x 310	2	4.7			4.7		
10135 - 0601 x 235	2	3.5			3.5		
10135 - 0601 x 280	2	4.2			4.2		
10135 - 0601 x 310	2	4.7			4.7		
10135 - 0601 x 260	2	3.9			3.9		
10135 - 0601 x 310	6	14.1			14.1		
Frames:							
Station	1						
10 .125 x 5 x 116	1	6.8			6.8		
20 .125 x 5 x 130	1	7.7			7.7		
30 .125 x 5 x 145	1	8.5			8.5		
44.4 .125 x 5 x 158	1	9.4			9.4		
59.6 .125 x 5 x 126	1	7.5			7.5		
78.3 .125 x 5 x 130	1	7.7			7.7		
82.8 .125 x 5 x 134	1	7.9			7.9		
94.5 .125 x 5 x 138	1	8.2			8.2		
105 10136 - 2402 182	1		23.2			23.2	
119 .125 x5 x 182	1	10.8			10.8		
129 10136 - 2402 182	1		23.2			23.2	
134 .125 x 5 x 182	1	10.8			10.8		
148 .125 x 5 x 182	1	10.8			10.8		
162 10136 - 2402 182	1	8.2			8.2		
174 .125 x 5 x 182	1	10.8			10.8		
184 .125x 5 x 182	1	10.8			10.8		
193 .125 x 5 x 182	1	10.8			10.8		
202 .125 x 5 x 174	1	10.3			10.3		
211 .125 x 5 x 172	1	10.2			10.2		
222 .125 x 5 x 170	1	10.1			10.1		
234 .125 x 5 x 165	1	9.8			9.8		
245 .125 x 5 x 153	1	9.1			9.1		
257 .125 x 5 x 142	1	8.4			8.4		
270 .125 x 5 x 132	1	7.8			7.8		
279 .125 x 5 x 121	1	7.2			7.2		

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS FOR MIG-15 AIRFRAME AND LANDING GEAR
(Continued)

Pounds

Item	Number of Pieces	Finished Dural	Finished Steel	Finished Total	Bill of Materials Dural	Bill of Materials Steel	Bill of Materials Total
Station							
300 .125 x 5 x 50	1	2.9			2.9		
309 .125 x 5 x 84	1	5.0			5.0		
320 .125 x 5 x 67	1	4.0			4.0		
Ducts							
0 to 44; Dural .065 x 84 x 48	1	24.8			29.0		
44 - 105 .065 x 75 x 60	2	59.0			75.0		
105 - 162 .065 x 48 x 55 (Top)	2	53.3			75.0		
104 - 162 .065 x 65 x 55 (Lower)	2	72.2			90.0		
Frame 44: Web .032 x 18 x 36	1	2.1			8.0		
Struts .094 x 1½ x 12	4	4.5			4.5		
Duct Stiffener .094 x 1½ x 84 in.	1	7.8			7.8		
Frame 105; Web .032 x 24 x 60	1	4.6			5.7		
Struts .094 x 1½ x 24	5	2.2			2.2		
Stiffener Alcoa .094 x 1½ x 84 in.	2	7.0			7.0		
Frame 162: Web .015 x 36 x 60 (18-8)	1		19.8 stainless			[illegible]	
Stiffeners, .094 x 1½ x 48	2	9.0			9.0		
Stiffeners, .094 x 1½ x 65	2	12.1			12.1		
Struts .094 x 1½ x 24	5	11.2			11.2		
Cockpit Floor .060 x 60 x 50	1	18.0			18.0		
Alcoa 10135 - 0601 x 60	7	3.2			3.2		
10135 - 0601 x 10	30	2.3			2.3		
Fuselage Skin							
0-44: .045 x 45 x 134	1	24.1			46.6		
44-105: .045 x 61 x 132	1	32.2			32.2		
44-134: .058 x 90 x 44	1	9.5			23.8		
105-162: .048 x 57 x 90	1	20.5			20.5		
105-162: .045 x 57 x 90	1	20.5			20.5		
105-210: .020 x 105 x 180	1	37.8			37.8		
162-234: .042 x 72 x 172	1	49.5			49.5		
234-320: .044 x 86 x 120	1	41.3			79.3		

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS FOR MIG-15 AIRFRAME LANDING GEAR (Continued)

Item	Number of Pieces	Finished Dural	Finished Steel	Finished Total	Bill of Materials Dural	Bill of Materials Steel	Bill of Materials Total (Pounds)
Tail Pipe							
(18-8) .032 x 63 x 30	1		(17.2 stainless)			(17.2 stainless	
Flange 1/8 x $1\frac{1}{2}$ x 32	1		(1.7 stainless)			(1.7 stainless	
Canopy	1	(44 glass and plastics)			(44 glass and plastics		
Armor Plate	1		330			330	
Total Body Group		952.4	376.4	1411.5	1094.4	376.4	1566.7
Landing Gear							
Wheel	3	(30 magnesium)			(159 magnesium)		
Brakes	3		55			165	
Tire, 6.6 x 26	3	(69 rubber)			(69 rubber)		
Tube	3	(15 rubber)			(15 rubber)		
Oleos, Main	2		100			400	
Nose	1		70			280	
Total Landing Gear			225	339		845	1088
Fuel Tanks							
Aft Fuel Tank							
Rear End, .040 x 490 sq. in.	1	1.9			3.1		
Front, .040 x 810 sq. in.	1	3.1			5.0		
Wrapper, OS .040 x 79 x 36	1	11.0			11.0		
Wrapper, I.S., 040 x 38 x 36	1	5.3			5.3		
Tops, .040 x 11 x 36	2	3.0			3.0		
Baffles .040 x 650 sq. in.	2	5.0			8.3		
Total Aft Fuel Tank		29.3		29.3	35.5		35.5
Forward Fuel Tank, at .3 lb./gal.	1	(85 rubber)			(85 rubber)		

	Dural	Steel	Stainless Steel	Magnesium and Alloys	Rubber	Glass and Plastics	Grand Total
Finished Weight	1919.0	1450.9	39		169	44	3661.8
Bill of Materials	2337.4	3335.9	52	160	169	44	6098.3

ESTIMATED FINISHED WEIGHT AND BILL OF MATERIALS
FOR MIG-15 AIRFRAME AND LANDING GEAR
(Continued)

Pounds

Item	Number of Pieces	Finished Dural	Finished Steel	Finished Total	Bill of Materials Dural	Bill of Materials Steel	Bill of Materials Total
Engine Mount $2\frac{1}{2}$ in. OD x .065 x 24	2		6.8			6.8	
$2\frac{1}{2}$ in. OD x .065 x 36	2		10.2			10.2	
$2\frac{1}{2}$ in. OD x .065 x 30	2		8.4			8.4	
Firewall Fittings, 6 cu. in. est.	6		10.3			12.0	
Engine Fittings, 7 cu. in. est.	3		6.0			7.0	
			41.7			44.4	